100 BOOKS SCHEME

THINGS AROUND US SERIES

FIBRES

PUBLISHED BY:

THE LOTUS TRUST,

BOMBAY.

Re. 1/-

Published by

THE LOTUS TRUST
Kodak House, Hornby Road,
BOMBAY.

COMPILED
by
M. H. KANTAWALA
"100 BOOKS SCHEME"
KODAK HOUSE,
HORNBY RD.,
BOMBAY

Printed by DHIRUBHAI DALAL
at the Associated Advertisers &
Printers Ltd.
[illegible], Arthur Road, Tardeo, Bombay 7

atise his general knowledge. It is to make up this deficit in the requisite equipment in India that this scheme has been prepared. In eight vernaculars in India, illustrated books on technical subjects, compiled with great care and bringing up-to-date information on the topics dealt with, would be brought out. They would be prepared on a uniform basis and there would be cross references and index volumes attached to the series.

The knowledge is not new. It is extant in the English language, in which there are many books available at 6d., 9d., 1s. 0d., 2s. 6d. and 5s. 0d. and more. These books are available only to readers in the English language, but they are written abroad and without specific reference to Indian conditions, whereas our intention is to have these books prepared carefully and wherever possible to bring in as many known facts relating to the subject from the Indian point of view, so as to make the book more useful to the Indian reader.

This is a task, which should have been performed by Government either in the Centre or in each respective Province. It is a task, which could have been handled satisfactorily by the various Universities in India. But it is an omission, which has very far-reaching consequences in the life of the people, and it was considered desirable by the Trustees of the Lotus Trust that this work should be attempted independently and carried through so far at least as the preliminary compilation of the books and the preparation of the necessary picture blocks was concerned. This work is indeed costly and for this purpose the Lotus Trust has set aside a sum of Rs. 25,000; a contribution of Rs. 18,000 was received from the Trustees of Sir Dorab Tata Trust, which is gratefully acknowledged. The translation in various provincial languages in India and the publication of these books in thousands of copies at a very cheap price, if possible, of about 4 annas, or a figure well within the reach of the poorest, is a task, which will still require finance and co-operation of a wide range, both official and non-official. Encouragement in the form of a money grant to the scheme has already been received from the Govern-

ment of India. Considerable progress has been made in the work of compilation.

Since this work was begun in the middle of 1944, some fifty out of a hundred and ten subjects have been already dealt with and others are in the process of compilation. The list of the subjects is elastic and some topics may be dropped out and others added to.

This series does not aim merely at benefiting boys in the teen age, who are attracted towards a subject. The series is also intended to benefit workmen and staff, who are engaged in industry and who desire to know more about the activity, from which they are deriving their livelihood. It is also intended to benefit University students and, above all, to benefit the general reader who wants to add to his knowledge on one or more topics. Many men know loosely many things about many subjects, but the knowledge is not systematic and it is derived frequently from hearsay. Many men would like to know fully about subjects, which attract their notice. The series would also be an invaluable addition to school libraries and, it is hoped, would help in raising the standard of general knowledge of vernacular teachers.

The growth of industry in India has been considerable in the manufacture of some articles and altogether negligible with regard to others; the spread of knowledge covering the whole field of "THINGS AROUND US" will doubtless stimulate interest in those things, which have hitherto failed to receive attention from entrepreneurs.

Another set of people, who, we expect, would benefit from this series when it is available in every Indian language, would be workmen, who have been rendered literate by the efforts of the State. Adult literacy is in the forefront of the national programme and it is our intention to make available something in which the grown-up man can find interest. The active worker, when he just begins to read, should have the chance to peruse in print the topic, in which most of the things are known to him by actual work.

Another object of this series is to remove the libel on the Indian workmen and the Indian humanity generally, that there are few inventions in India. This is entirely due to the accident that improved machines are brought from abroad and even when the Indian handles them and repairs them. he has not a vivid mental picture of the whole process or the whole purpose. Once the Indian workman has full knowledge of the industry in which he is engaged, I am confident that the Indian mind is capable of inventions, which will astound the world. India must stop importing in the mass equipment from abroad except sample models, and the illiteracy of the workman and the peasant must be liquidated. The effective spread of knowledge through the books compiled in this Series in all Indian languages would then bear fruit; the farmer will cease to be conservative and the workman will have the courage and good sense to make suggestions involving greater convenience for himself and leading to improvement of the process and of the machines

Kodak House,
Hornby Road, Bombay.
1st March, 1948.

MANU SUBEDAR,
Chairman,
The Lotus Trust.

100 BOOKS SCHEME.

Topics on which compilation is completed

1. Rubber
2. Coconuts
3. Lighting Materials
4. Cotton
5. Wool
6. Rivers
7. Mountains
8. Sea
9. Ships
10. Light
11. Astronomy
12. Geology
13. Soils
14. Flowers
15. Fruits
16. Foodgrains
17. Seeds and Kernels
18. Vegetable Oils
19. Mineral Oils
20. Coal
21. Tobacco
22. Coffee
23. Fibres
24. Motor Car
25. Paper
26. Non-Ferrous Metals
27. Insects
28. Precious Stones
29. Plastics
30. Matches
31. Bee-keeping
32. Stone
33. Silk and Art Silk
34. Noble Metals
35. Gums and Resins
36. Roads
37. Power
38. Watches and Clocks
39. Microscope
40. Air Conditioning
41. Meteorology
42. Telegraph and Telephone
43. Photography
44. Dyestuffs
45. Glass
46. Sugar

Topics on which compilation is progressing

1. Tea
2. Salt
3. Soaps
4. Inks
5. Cement
6. Manures
7. Colloids
8. Condiments
9. Architecture
10. Aeroplane
11. Radio
12. Nutrition
13. Sanitation
14. Care of children
15. Anthropology
16. Fisheries
17. Geography
18. Irrigation
19. Machine tools
20. Workshop
21. Minerals
22. Archaeology
23. Block Making
24. Printing Press
25. Boilers
26. Mechanics
27. Cinematography
28. Disinfectants
29. Electricity
30. Explosives
31. Internal Combustion Engines
32. Perfumes
33. Musical Instruments
34. Paints and Varnishes

Topics on which compilation is not yet taken in hand

1. Iron and Steel
2. Timber
3. Leather
4. Furniture

5. Type Foundry
6. Forestry
7. Agriculture
8. Animal Husbandry
9. Food Preservation
10. Public Health
11. Market Gardening
12. Knitting and Sewing
13. Cookery
14. Nursing
15. Laundry
16. Cleanliness
17. Typewriter & Comptometers
18. Pencils & Crayons
19. Cotton Textiles
20. Pottery and Ceramics
21. Abrasives
22. Ice & Aerated Waters
23. Book Binding
24. Chemistry
25. Botany
26. Zoology
27. Biology
28. Physics
29. Physiology
30. Railroad
31. Public Works
32. Armaments
33. Pictures & Picture Frames
34. Carpets
35. Fountain Pens
36. Carpentry
37. Fire-fighting Equipment
38. Drawing Materials
39. Buttons

(Contributions or co-operation from scholars and others interested in these topics would be welcome.)

FIBRES

CHAPTER I

INTRODUCTORY

Definition

The word 'Fibre' conveys the idea of any thread or thread-like substance and is generally used to denote thread-like tissues found in the animal or vegetable kingdoms. An endeavour will be made in this book to describe all such fibres as are utilised in industry, though it will be outside our scope to give detailed descriptions of the various manufactures from fibres, most of which are dealt with in other books belonging to this Series.

Classification

All fibrous material that is industrially useful can be divided into three classes, animal, vegetable and mineral, according to the source from which it is derived. Or, it can be divided into several classes according to the uses to which it can be put: thus, textile fibres like **cotton** and **wool** can be distinguished from fibres used in the manufacture of paper or brushes or in the upholstery industry. The several industrial uses of fibres depend mostly on their nature and composition; the rougher and coarser texture of some being adaptable for uses to which the softer and smoother ones are not quite suited. The commercial forms of all fibres are more or less elongated filaments which may be either straight in shape like horse hair or cereal straws, or curved or twisted like cotton and coir.

Animal Fibres

Animal fibres appear to have been intended by nature to subserve protective functions. They may be either epidermal hairs or furs like **wool, mohair, alpacca, camel**

hair, etc. which act as a protective coating to the different animals, or cocoons of silk which are sheaths spun by the larvae of certain insects in passing from the pupa or resting stage. In any case, animal fibres have certain properties in common which help to distinguish them from the vegetable group. They are poor conductors of heat and are therefore warmer to wear; they burn only with difficulty and emit a distinctive smell of burnt hair; they resist the action of weak acids but are destroyed by alkalies like soda; they therefore react differently towards different dyestuffs. As an illustration of the last property, we may mention the following experiment. When a piece of cotton and a piece of wool are placed in a cup of hot water to which a few drops of red ink are added and are rinsed in clean water after 15 minutes, the wool will show a more or less deep red colour but the cotton will soon wash white again. Animal fibres are all individual detached units of varying dimensions Thus sheep's wool is about a yard long though for textile purposes it is shorn at lengths of 2 to 16 inches. Horse hair is used in lengths of 4 to 24 inches and silk which on reeling measures hundreds of yards is spun in broken lengths, depending upon the fabric.

Vegetable Fibres

Vegetable fibres on the other hand like **cotton, linen, jute, ramie** and even **artificial** silk which has a vegetable base are cooler to wear and being composed of cellulose absorb moisture easily They can be burnt with comparative ease and emit on burning a distinctive acrid smell like that of burnt sugar. They are easily tendered by acids but are not destroyed even by strong alkalis. This last property is availed of in the manufacture of brushes used for whitewashing where the specially resistant character of vegetable fibres is regarded as proof against destruction through continual immersion in alkaline solutions.

Bast Fibres

There are numerous kinds of vegetable fibres possessing diversified characteristics Only in **seed-hairs** like cotton or kapok they are individual units consisting of

single long narrow cells free from transverse partitions; otherwise they are elaborate and complex aggregates and occur as **bast tissues** in dicotyledonous plants or as **fibro-vascular bundles** in monocotyledons. All plants possess a certain amount of mechanical tissue, which not only enables them to support heavy weights at their summits but also gives them a wonderful degree of elasticity. Thus, a rye haulm which is about 5 feet high but hardly .1 inch in diameter bends before the wind only to return to its original position when the force of the wind has been spent. This stability is given to it both by **stone cells** as well as by **bast fibres.** The latter, also known as **sclerenchyma fibres,** are narrow, elongated, spindle-shaped cells with pointed ends, polygonal in transverse section (as shown below) and offer resistance to tearing through interlocking. It is estimated that their sustaining strength in life is in general equal to the best wrought iron or hammered steel.

Ultimate Fibres

The bast fibres have generally obliquely-placed narrow elliptical pits. Their cell-walls may be or less lignified as in **hemp** or complete unlignified as in **flax.** They only become mature in fully grown parts of the plant. These fibres aggregate themselves into bundles or "**ultimate fibres**" varying from 3 to 20 and the divisibility of these bundles in the processes preliminary to spinning is an element in the textile value of the raw material. This value however is more determined by the length of the fibres which determines their cohesion and therefore the tensile strength of the yarn into which they are spun. Though the average length of a bast fibre is hardly 1 or 2 mm., fibres of economic importance are considerably longer. Thus while jute fibres are between 2 to 3 mm. long, those of flax from which linen is made are between 25 to 35 mm. long, while ramie varies from 50 to 250 mm. This variability detracts somewhat from the value of the material for spinning purposes.

Vascular Fibres

Among monocotyledons, the fibre aggregates are supplied by what are known as **fibro-vascular bundles** of leaves and stems which form conducting tissues for water etc. from one organ of the plant to another. These bundles cannot be subdivided like bast fibres and do not possess the true spinning quality as they cannot be drawn or twisted into weaving yarn. In this group fall **sisal**, **manilla**, **coir** etc. whose fibres are only useful for stringing or cordage. There are still more complex fibres, like the stems of **esparto**, **straws**, **palm** leaves etc. which cannot be woven but can be plaited into mats, hats, etc. or which constitute the raw material for the manufacture of paper, strawboards etc.

Mineral Fibres

Among mineral substances the only really fibrous material is **asbestos** which can be spun or twisted into coarse textiles. Artificial processes are however employed for transforming certain inorganic substances into raw material of a fibrous character: thus, glass and slags are fused and drawn or spun to continuous fibres known as "glass-wool", sometimes used in weaving. Similarly, a number of metals are drawn out to very fine dimensions of continuous lengths which are afterwards woven into cloth or gauze, certain **metallic fibres** being woven into textile fabrics used as dress materials for producing either fancy effects or fire-proofing or acid-resisting qualities.

Textiles

Any economic classification of fibres according to the uses to which they are put must be arbitrary, as some fibres are employed for several purposes like cotton, for instance, which is used not merely in the textile industry but also for manufacture of cordage, paper, etc. However, under this classification fibres can be divided into six distinct groups. The first and the most important group is the **Textile group** which would comprise cotton, silk, wool, rayon, flax, hemp, ramie, jute etc. Here, except silk which

is generally in continuous lengths and rayon, the fibres have to undergo elaborate processes of scutching, hackling, combing etc. so as to produce uniform parallelised units which can be laid together and drawn into continuous bands of sliver and roving to be finally drawn and twisted into yarns. The processes differ for different fibres and are highly technical.

Cordage

The next group includes **cordage fibres** like manilla, sisal, hemp, coir, banana, etc. This and the last group are certainly not exclusive, as hemp is included in both and cotton is also used for manufacturing twine etc. However, there is one common feature between the two groups, namely, that the unit or aggregate threads of fibres with or without preliminary treatment must be wound together and suitably twisted or spun, except in the case of **binder twines** used in horticulture from the Raffia leaf or the Banana stalk. There are many local fibres which are twisted into ropes for local use.

Brush-ware

The third group comprises **brush and broom fibres.** Brushes in common use are of many different forms and texture and the animal fibres or bristles that are required in their manufacture are supplied by the badger, hog, sable, bear, squirrel, horse etc. Cleansing brushes require hard and resilient fibres like tail hairs, while fine painting can only be done with soft camel hair "pencils". Dusting and scraping brushes require hard bristles like coir, palmyrah, kitul, piassava, and many other vegetable fibres or even wire. Some of the softer vegetable fibres, like aloe, agave etc.; are used for plasterers' and whitewashers' brushes, whisks, mops, etc., being resistant to alkalis like lime or distempers, though large wall brushes are sometimes made like brooms from coarser fibres obtained from trees of the palm family. Soft brooms are sometimes made from bundles or sheaves of twigs or leaves tied together in a handy form with or without handles.

Stuffings

The next group comprises **stuffing materials** used for stuffing or filling in connection with mattresses or seats and cushions in upholstery. Mattresses in India are generally stuffed with cotton, but this fibre has a tendency to become matted and compressed which necessitates its occasional removal and re-teasing or carding. The roving teaser stringing a jazzy note on his carding bow to invite customers is not an unfamiliar figure on many a roadside. This defect of cotton is avoided in other countries which use flosses or seedhairs of kapok or tree cotton which are soft, silky and resilient. We have another plant, the milky Akda, which produces in its pods a good floss that can be put to a similar use. The softer bristles of coconuts also provide mattress fibre largely used for stuffing. Among the animal fibre used in upholstery may be mentioned horse-hair, wool flocks and some short animal hairs and wastes.

Paper

The **paper making** industry has no use for animal fibres but can employ almost any and every vegetable fibre. Though the bulk of the raw products of paper are supplied by rags, waste paper and wastes from the textile industry, any fibrous material which contains over 30% of cellulose and yields ultimate fibres of 1 mm. length and over can be used in the industry. This is how esparto and other grasses, cereal straws, bamboos etc. have come into use, along with wood pulps prepared by chemical or mechanical treatment from forest trees like pine, spruce, poplar etc. Alkaline boiling resolves the fibres and pulp into cellulose generally known as **half-stuff** which is subsequently bleached, before using. Paper is but a web of short units produced by deposition from suspension in water and agglomerated by the interlacing of the component fibres in all planes within the mass.

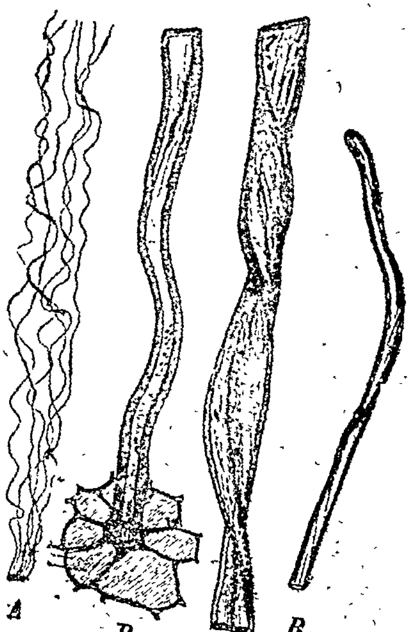
Miscellaneous

Finally, the miscellaneous group would include such fibres as do not fall in any of the above groups and include

eri and muga, over half a million lbs. We produce a number of other fibres which are industrially useful, even pig's bristles collected in the United Provinces being exported or used in the local manufacture of brushes. We manufacture pulp for paper but not for rayon though we have factories for weaving imported yarns. We do not have asbestos mines though we have facilities for manufacturing other metallic fibres.

through the scutching and the carding machines where final cleansing of the impurities has taken place prior t spinning. These fragments appear in most unbleache yarns as small black specks known as **'motes'.**

The individual cotton fibre is a single hollow cell with- out any transverse partition and is formed by the outgrowth of single epidermal cells of the testa or the outer coat of the seed. In the following illustration, the first figure re- presents a portion of the seed-coat with its hairs and is enlarged three times. The other three figures multiplied three hundred times show respectively the lower middle and upper portions of a hair. The fibres are not of uniform diameter throughout and taper towards the outer end, the tail being devoid of the central canal or **lumen.**



A B₁ B₂ B₃

Cotton fibres, when viewed under the microscope, appear to be flattenned and twisted, resembling somewhat in general appearance an empty and twisted fire-hose.

This characteristic is of great economic importance as the natural twist facilitates the operation of spinning the hairs into threads or yarn. This twist is not present in the early stages but only becomes developed after the boll has opened and the cotton has been exposed to sun and air. It is said to be due to the withdrawal of the living cells from the central canal on such exposure and to the filling up of the canal with air and lateral compression. The twists are sometimes in one direction and sometimes in another, occur at irregular distances from one another and vary in the degree of convolution. The finer the diameter of the fibre, the larger the number of twists: they are thus more numerous in Sea Island cotton which is said to be the finest variety of cotton in the world. These twists enable the fibres to exert a certain amount of grip on one another and to interlock like cork-screws when they are subjected to spinning; the twists also produce a certain amount of elasticity, cotton fabrics being much more elastic than those of linen whose fibres have no twisted structure. Unripe cotton fibres do not show this spiral twist and are technically known as 'dead cotton': they break up in the process of manufacture and increase the amount of waste. When present in fabrics they do not take up dyes satisfactorily and thus produce 'neps' or light-coloured tufts on darker material.

A well-formed cotton fibre is about 0.004 mm. thick, full length being about 2000 times this diameter. But the length varies in different varieties and cotton is classified commercially according to its length into long, medium and short-stapled. Long stapled cottons like the Egyptian, Peruvian and Sea-island are from about 1¼ to 1½ or more inches in length: medium-stapled like the American Upland varies between 7/8 to 1 inch and the short-stapled like the Indian from 3/8 to 3/4 inch. The colour of the cotton also varies, the American being quite white and the Egyptian pale brown which however can be bleached. The blue memphis of America is a faint grey which is difficult to remove. In chemical composition, cotton consists of pure cellulose, about 90 per cent, with about 7 to 8 per

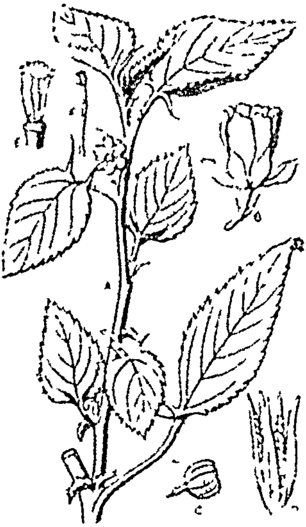
cent of water, 0.4 per cent of wax and oil, 0.6 per cent of nitrogenous substances and 1 per cent of mineral matter. The wax or oil makes the fibres incapable of absorbing water so that in the preparation of absorbent cotton used in surgery, it has to be removed by boiling in a dilute solution of caustic alkali under pressure and subsequent treatment with bleaching powder and hydrochloric acid and lavation. When cotton is immersed in a strong solution of caustic soda, a silky lustre is produced, this phenomenon being developed as the process of '**mercerisation**'. The structure of the fibre undergoes alteration, the flattenned twisted tubes being converted into hollow cylindrical forms through swelling. There is also a decrease in length with an increase in tensile strength. It is said that Egyptian cotton mercerises better than other varieties. If cotton is treated with a mixture of nitric and sulphuric acids, it becomes **nitrocellulose** or **gun-cotton** which can explode on percussion and burn with a flash. On dissolving nitrocellulose into ether or a mixture of ether and alcohol, we get **collodion** which is used for preparing photographic plates or manufacturing **celluloid.**

Ginned cotton is offered in the form of bales which weigh 400 lbs in India, 480 lbs. in America and 750 lbs. in Egypt. These bales on reaching the textile mills are opened out in the bale-breaker whose function is to break and tear the hard compressed slabs of cotton into a fairly fluffy state. The functions of the various processes in fact through which cotton is machine-converted into cloth can be summarised as follows: "(1) to reduce the highly compressed cotton from the bales into the greatest possible state of division i.e., to the ultimate fibre and at the same time to remove sand, leaf, broken seed and short fibres; (2) to form the fibres into a rope or sliver which can be attenuated by stages until it is thin enough to form the required thread; (3) to parallelise the fibres by drawing between rollers or by combing and at the same time by combing and attenuating several slivers to increase the regularity of the material; (4) to insert sufficient twist into the product of the final attenuation in order to make a firm thread; (5) when

required, to combine one or more single threads into a folded yarn; (6) to finish and prepare the yarn for transport or for weaving; and (7) to weave the yarn into cloth by interlacing horizontal (warp) with vertical (weft) yarns".

Jute

Jute is one of the cheapest fibres, occupying a position in the manufacturing scale inferior only to that of cotton and flax. In India which supplies practically the whole of the crop it ranks next to cotton. Attempts have been made to grow the plant in America, Egypt, Africa and other places but the fibre produced there is much inferior to Indian Jute which thrives best in the hot moist climate of eastern and northern Bengal. There are two species of the plant (**Corchor capsularis** and **C. olitorius**) which in almost all respects except in the shape of fruits and size are very similar to each other, the former being cultivated in Central and Eastern Bengal and the latter near Calcutta. The following diagram shows a jute plant with the capsules of the two species in the bottom right-hand corner—



These plants are annuals, growing about 8 to 15 feet high and possessing long, straight, cylindrical stems, about

surface of the water and draws it through the water so as to wash off the bark and other impurities. Then, with a dexterous throw, he fans out the fibre on the surface of the water and picks out the remaining bark or black spots. The fibre is now wrung out to remove water and is hung on lines to dry. When dried in the shade, the colour develops better than in the sun. No machinery whatever is used, except a wooden beater in some localities, for separating the fibre from the stem. The separated and dried fibre is made up into bundles and sent to the jute presses where it is sorted according to colour and quality and packed in bales of 400 lbs. each. One acre yields about 3 bales; the annual crop of India is usually between 8 and 9 million bales. Originally, the fibre was used locally for manufacturing cordage and gunny bags through hand labour. Then England started importing and Dundee became the chief seat of jute manufactures. The success of the *mechanical methods of spinning and weaving there led to* the establishment of jute mills in and around Calcutta for manufacturing hessians, sackings and latterly jute canvas, in which half our total production of jute is consumed: but Dundee still continues to produce the better kinds of fabrics including carpets, rugs, matting, tarpaulins, scrims and mixed articles, while other countries too have commenced manufacturing. As jute fibre is woody and brittle, it is subjected to preliminary treatment of 'batching', crushing and softening before it can be carded and drawn into slivers and roves for spinning. Jute yarn is 'counted' by its weight in lbs. per "spyndle" of 14,400 yards, the finest weighing 2½ lbs. while the coarsest exceeding 300 lbs. The warp and weft of jute are known respectively as **'porter'** and **'shot.'** Jute can be dyed to any shade but is not fast to light: as it can simulate human hair on dyeing, it is used for making wigs. It cannot be bleached satisfactorily.

Jute consists of strands of fibre which vary from 6 to 10 feet in length and sometimes more. The best quality is of a clear whitish yellow colour with a nice silky lustre, soft and smooth to the touch and fine, long and uniform in fibre. The walls of the separate cells composing the fibre

vary in thickness at different points so that the single strands are of unequal strength. Each strand is composed of a large number of ultimate fibres varying from 2 to 5 mm. in length and from about 0.02 to 0.025 mm. in diameter. A transverse section of a jute filament shows from about 8 to 20 ultimate fibres, more or less polygonal, thick-walled and with a fairly wide but irregular lumen. Their surface is smooth and free from transverse markings peculiar to flax fibres, but the striations if any are parallel with the fibres. Jute differs from cotton, flax and hemp in chemical composition, its cellulose being highly lignified. It is much weaker than flax or hemp and is not so durable. It is highly hygroscopic and can absorb as much as 23% of moisture under damp conditions: it is thus liable to undergo deterioration in storage or transit. The fibre at the base of the stem, being hard and coarse, is cut off for about 6 to 8 inches before baling, these root-ends or "**butts**" being baled separately for paper-making. The four chief varieties are known as the softer **Serajgunje**, the stronger **Naraingunje**, the low-coloured **Daisee** and the harsh **Dowrah**; each class being again subdivided according to colour and quality and receiving a distinctive 'baler's mark' which plays a very important part in the trade.

There is a cess on the export of jute from India at the rate of two annas per bale of 400 lbs. (same as for cotton) and on manufactured articles, twelve annas per ton.

Other Jutes

Though there is no true jute grown in India outside Bengal and Assam, there is a considerable area (about 165,000 acres) in Bombay and Madras under **Bimilipatam jute**, also know as **Deccan hemp** in Western India. This is a different plant altogether, **Hibiscus Cannabinus, (Ambari)** but yields a fibre which is very similar to jute and is put to practically the same uses and fetches the same price as medium grades of jute. It competes with jute in South India for the production of what are known as "Heavy C's" which are hemmed bags 40" long and 20" broad with a coloured stripe. The normal outturn is about

improving upon the two time-worn systems of water-retting and dew-retting. **Water retting** is generally practised all over the world and consists in steeping the bundles of flax into water. The water should be pure and soft: otherwise the fibre becomes discoloured. The steeping is done either in ponds or in slowly running water. The rippled bundles are placed flat or root downwards in water and are covered over with sods or clods and weighted down by stones or weights to keep them submerged. Fermentation soon sets in and is manifested by the evolution of gaseous bubbles. as fermentation subsides, the flax begins to sink This takes between ten days to two weeks. The bundles are examined from time to time to see whether retting has proceeded far enough. When the fibre can be readily separated from the woody core, the bundles are withdrawn from the water and stood on end (stooked) or laid out on grass to dry. The drying takes between a week and fortnight, the stalks being turned over several times in the interval to secure uniformity in drying. The finest flax fibre in the world is obtained from the Coutrai district in Belgium where rippling and retting are not done immediately the crop is harvested but are postponed till the next season, the stalks being dried and stacked in the meanwhile. Retting is done there by packing the straws, root endwards, in the crates which are wound round the sides by strips of jute-sacking and placing these crates in the river Lys weighted down with stones. When the retting is complete, the crates are withdrawn and the straw is removed and dried in the air: sometimes they are repacked and immersed for a second retting. Many other variations have been suggested in the method of ordinary water retting, the patented Schenk process requiring immersion in vats of warm water or the Legrand process requiring the use of a series of three tanks and successive immersion in each. **Dew-retting** is practised only in the Archangel district of Russia. The freshly pulled stalks are spread out in rows on moist grass and exposed to the action of sun, air, dew and rain for a period of about two or three weeks. The straw is turned over from time to time. The

process is tedious and the fibre is brown in colour although it acquires a soft silky texture.

The next process is **'breaking'**: by this is meant the breaking up of the internal woody core into soft pieces. This is achieved by passing the dry retted stalks between a series of six to twelve pairs of grooved or fluted rollers so arranged that each pair works more closely than the previous one. The fibre is now ready for the 'scutching' mill which scrapes off the woody matter not separated in the breaking process. Hand labour is still much used for both these processes on the Continent and Ireland but scutching is now generally done in a machine provided with a revolving cylinder or drum which has tough flexible wooden blades at the periphery. These blades strike the flax and expel the fragments of wood. A certain amount of fibre is wasted and this waste known as **'codilla'** is used for spinning yarns for twine, canvas etc. After scutching, the fibre is sorted into different grades, tied into small bundles and packed into bales under pressure.

Each flax filament is composed of a group of ultimate fibres and varies in length from 12 to 36 inches. The average diameter is 0 006 inches. The ultimate fibres which are 0 3 to 1 5 inches in length are regular and more or less cylindrical with occasional joint-like swellings or nodes giving them a bamboo like appearance. The walls are thick so that the central cavity or lumen is small or absent, thus producing tenacity. The outer walls have transverse markings which prevent the fibres from slipping over one another in spinning and which also give linen fabrics better durability. The best flax fibre is of a pale yellow colour dew retting gives a greyish and incomplete retting a greenish tint. The fibre is soft and lustrous and stronger and more durable than cotton. It is a better conductor of heat so that linen fabrics feel cold to the touch. The finest flax fibres are used in the manufacture of damasks, sheetings, cambrics and other linen fabrics including thread and lace while the coarser qualities are woven into canvas, hollands, sacking and twine.

The yield of fibre is said to be between 4 to 5 cwts., per acre, the proportion of fibre varying from 8 to 20 per cent the weight of the rippled straw. Flax fibre is generally known in the market by the name of the district in which it is grown. Belgian grades are superfine, long and of an excellent colour. Irish grades are famous for their softness, fitness and good colour. Italian grades are much more lustrous. Russian flax is of good length but of medium or low quality. French and Dutch grades are said to be of very good quality, the word **cambric** being derived from the French district Cambrai whose flax yielded a white fabric. The cultivation and preparation of flax appears to be the most ancient of the textile industries, evidence of its use being found as far back as the stone age. Linen was the only material which the priestly order of Egypt was permitted to wear and in which embalmed bodies are found to have been wrapped.

Hemp

Hemp is a fibre derived from the stalks of the plant, **Cannabis Sativa,** which is sometimes known as the **Ganja** plant, because the dried flowering tops of the cultivated female plants form **ganja**; the resin derived from the stalks and leaves form the narcotic **charas,** the dried leaves and flowering shoots form **Bhang** and a preparation from the leaves, the Turkish **Hashish.** In fact, the plant is cultivated in India, Arabia, Africa and Mexico mainly for these narcotics though in all European countries and in America it is cultivated for its fibre. There are other varieties of hemp like **Mauritius hemp, Bow-string hemp** etc. which may be regarded as Psuedo-hemps and which will be described in the next section.

The true hemp-plant is an annual and grows to a height of 4 to 10 feet or even more. It has a straight, erect undivided stem with small inconspicuous yellowish-green flowers. There are two kinds of plants, one bearing male flowers and the other female flowers. The latter bear seeds which contain 30 per cent of an oil similar to linseed oil and are cultivated in China, Manchuria and parts of Russia

for the sake of this oil. The female plants take about three weeks longer to mature than the male plants but where hemp is cultivated for its fibre, both the plants which look alike till flowering time and grow indiscriminately, being sown broadcast, are harvested at the same time. *The crop is ready for gathering* when the male plants change their colour from deep green to light brown. The plants are either pulled by hand which yields a better fibre or cut with a straight-bladed sickle which sometimes leaves the best fibre in the stubble. In America, the crop is gathered by reaping machines or hemp harvesters which cut swaths and lay them smoothly on the ground where they remain for three to six weeks for retting, when they are picked up by another machine which binds the stalks into bundles. These bundles are then kept in shocks to dry after which they are taken to the scutching mills.

Hemp, like flax, is a bast fibre and the various processes by which the fibre is separated from the stalks and isolated from the binding pectose matter are almost similar to those for flax. In most countries, except France, the stalks are laid out on the ground or set up in shocks to dry before retting. Retting is either **water-retting, dew-retting** or **snow-retting.** In Italy and many European countries, the stalks after curing in the shock are tied in bundles and left in water from 10 to 20 days covered over with straw or sods and loaded with stones or logs. Standing water is said to yield softer fibre than running water though river retting is considered to yield better results in France. After retting is complete, the stalks are washed with fresh water and dried in the sun: when quite dry, they are again made up into bundles and stored in barns preparatory to scutching. Dew-retting is practised, as we have seen, in America and also in some parts of the Continent. This is done by exposing the stalks on the ground to the action of dew and rain. Snow-retting prevails in Sweden and North Russia, the stalks being spread out to be covered by snow-falls and left there until the snow has melted away.

After retting the hemp is broken and scutched in practically the same way as flax. Wooden hand-brakes are

used for breaking: sometimes rapidly revolving fluted rollers are employed. The woody portion is thus broken into small pieces known as **hurds**. The fibre is then held by hand, the loosened hurds being beaten away through smooth projections on revolving cylinders. In America, breaking and scutching are done by machinery, the broken hurds being used as fuel for generating steam. The preparation of fibre in Japan is somewhat different. The bundles of stalks are subjected to the action of steam for a few minutes and then dried in the sun: they are again thoroughly wetted and heaped on straw mats for fermentation. The fibre is then stripped off by hand and immersed in water. The outer skin is removed by hand-scutching and the fibre is hung out on bamboos to dry. The fibre so obtained is in the nature of thin straw-coloured ribbons.

Hemp fibre consists of narrow flat strands from 3 to 10 feet long: its ultimate fibres vary in length from 0.2 to 2.2 inches. The lumen is fairly wide except towards the end. The surface bears numerous striations but has no nodes as in the case of flax. The fibres are forked at the ends so that hemp fibres can be easily distinguished from flax. Dew-retted hemp is grey, snow-retted greenish, and water-retted yellow. The best hemp is the Italian Bolognese variety which has an excellent colour and silky lustre, being often used as a substitute for flax to which it is more nearly allied than any other fibre. Hemp is a stronger and more durable fibre than any other except flax. For many years it was the only fibre used for ropes and sacking, for which other fibres have now been substituted. Hemp fibre is now used in the manufacture of strong tying and sacking twines, book-binder's twines, shoe and harness thread, net twine, carpet warp, canvas, sails, tarpaulins and superior ropes. Hemp tow, beaten out in the scutching process, is used in tarred oakum and also for packing for pumps and engines. The commercial value of the fibre depends upon its colour and lustre, the nearly white or pale grey varieties being regarded as the best and the soft yellowish kinds the least valuable. The fibre is more cuticularised than flax and, being devoid of elasticity and flexibility,

is rarely used in the manufacture of fine textiles. The yield of dry stalks per acre is between 2 to 3 tons, 25 per cent of which yields hemp; of this about two thirds is spinning fibre and the rest tow. The cultivation of hemp proper is controlled by license in India, only a limited acreage being allowed: there is, therefore, no true hemp fibre produced by us, our so called hemp being a mixture of fibres obtained from other plants.

Pseudo-hemps

There are a number of fibres which are known as one or another form of hemp but which are derived from different plants altogether. Thus **Sann hemp** or **Bombay hemp** which we export from India in large quantities is the produce of the plant, **Crotolaria juncea**, which is often grown in cultivated areas to serve as green manure. Before the value of jute was commercially recognised, the East India Company was exporting this fibre to England to serve as a substitute for Russian hemp. The plant grows to a height of between 6 to 10 feet. The crop is harvested mostly during the flowering stage by uprooting: the stems are allowed to dry and the leaves and fruits are removed: they are then tied up into bundles and kept submerged in pools of water, same as jute. Retting is complete in about 5 days. The bark is then stripped off and these strips are beaten with sticks or dashed against water for cleaning. When clean, the water is squeezed out from the strips which are hung out on lines to dry. The yield is between 3 to 4 tons of stems producing 5 to 6 cwts. of fibre per acre. Sann hemp resembles European hemp but is not as strong, though it is more durable than jute. The colour varies from grey to pale yellow. The strands are 4 to 5 feet long, the ultimate fibres of which they are composed being 0.2 to 0.4 inch in length. It is essentially a cordage fibre but is also made into canvas and bags as a cottage industry. For export purposes, there are different grades for the three ports of Bombay, Calcutta and Madras; and, along with combed fibre, a little tow, being the short ends of the fibre, is also exported for use in shipbuilding. We export

about forty thousand tons of hemp fibre, the bulk of which goes to the United Kingdom and the Continental countries.

Sisal hemp is derived from the leaves of **Agave Sisalana** and other species of Agave which are often wrongly known as Aloes. The word Sisal is derived from the name of a port in Yucatón, Mexico, from which the fibre was first exported. The various species have been introduced into many tropical countries as it is a hardy plant and can grow even on rocky or stony soils. The Sisal plant has a short globular stem bearing at its crown a number of thick fleshy leaves, between three to six feet in length, as shown below :—

After a few years, the plant produces a flowering stem or pole more than 20 feet high which bears buds in the axils of the flower-stalks. These buds develop into '**bulbils**' which are small plants and are used for propagation. The leaves are ready for cutting after about three years and are plucked yearly till the pole is formed, that is, for about 15 years. In East Africa, the average life is only about six years as there are two growing seasons but the yield

of leaves and fibre is almost double. In some countries, the yield is about 25 leaves per annum. An average yield may be reckoned as at least a ton per acre. The fibre is extracted by crushing and scutching. In Mexico and Africa this is done by a machine known as the raspador. The leaves become crushed and the pulp and tissues are scraped away: the fibres are then washed with clean water, dried on lines and brushed. Indian production is small and the extraction of fibre is mostly manual. The Sisal fibre is 3 to 5 feet long, white or pale yellowish, and harder than manilla. The ultimate fibres have a large polygonal lumen. In Sisal plantations, the leaf refuse is often used as manure but has been suggested as raw material for paper manufacture, as a source of alcohol, or even as feeding stuff. There are many other species of Agave yielding fibre, including the **henequen hemp** of Mysore which grows with success on waste lands.

Resembling Sisal is the **Bow-string** hemp or **Moorva,** the produce of various species of **Sansevieria** which grow in India, Ceylon, Africa, East Indies and China. These plants also resemble Aloes, but are grown from Suckers thrown out by their large underground stems or rhizomes. They are not yet cultivated systematically and the fibre is extracted from the succulent leaves of stray plants growing wild The extraction is similar to that for sisal. The leaves of the Indian species are not longer than four feet, and the fibre is used for making ropes, mats or coarse cloth.

Resembling Sisal is also **Zazape hemp,** the fibre produced from the succulent leaves of Zazape agaves of Mexico. These plants yield a larger quantity of fibre than sisal and the fibre is fine and of excellent quality. Another agave of Mexico yields the **Tampico hemp or istle.** Only the middle leaves are gathered and scraped after their thorny margins have been stripped; the fibre so obtained resembles sisal hemp but is pale yellow, and is used as a substitute for animal bristles for making nail and scrubbing brushes.

New Zealand hemp is derived from the leaves of **Phormium tenax** which grows extensively on the sea

boards of New Zealand and which has been introduced to some extent in Scotland, the Azores, South India and Africa. The plant is similar to the last two and has several varieties. The leaves are long, sword-shaped and folded in two. Propagation is through seeds or through root-cuttings. The plants usually grow in bunches of about 10 shoots, each producing five leaves. The leaves are cut after the plants are five years old, and a crop of three or four leaves can be obtained each year. The indigenous population prepare the fibre from the upper part of the leaves, scraping away the soft tissues with mussel-shells and soaking the fibre in water and drying it. Now, the fibre is extracted through machines consisting of horizontal fluted revolving rollers between which the leaves are introduced for scraping. The fibre is then cleaned through revolving brushes and passed through finishing machines, where the strands are isolated as filaments. The fibre is then soaked in water and bleached and dried in the sun. It is made up into hanks of 5 lbs. and packed in bales of 400 lbs. each. The average yield per acre is 10 to 15 tons of green leaves, often more, 7 or 8 tons of leaves producing one ton of fibre. The colour varies from white to pale reddish brown and the fibre is soft, flexible and lustrous. Hand-prepared fibre is as soft as flax and is used for textiles because the ultimate fibres can be separated by friction and fine filaments can be obtained; but the machine-made fibre is coarse and suitable only for ropes, twine and floor-matting. The cellulose of the fibre is strongly lignified.

Mauritius hemp is obtained from the Aloe plant **Furcraea gigantia** which is similar in its habitat to sisal or Agave and grows mostly in Mauritius. The leaves are thick and fleshy and the pole of inflorescene, often 30 feet long, bears numerous bulbils. The fibre is extracted from the leaves by means of a machine known as the gratte or scraper similar to the raspador of Mexico; it is then washed with water and soaked in a soap solution for about two days, again washed and then dried in the sun, brushed and made into bales. It resembles sisal hemp in general appearance but is finer, softer and weaker. It is used for

mixing with sisal and manilla or is twisted into cordage by itself.

Manilla hemp, as the name implies, is almost exclusively produced in the Philippines; it is also known as Abaca fibre. It is obtained from the leaf-stalks of a plant (Musa textilis) very much allied to the plaintain or banana and resembling it in many respects. The stem as in the case of the latter is sheathed by overlapping leaf-stalks or petioles, between 16 to 25 in number. From the underground stem or rhizome, shoots sprout up near the parent plant and grow in a cluster. Just before the latter flowers, the stalk is cut and the petioles are stripped off. The outer layer is separated from the inner which contains soft and weak fibre. The outer layer is then cut into strips which are drawn between a wooden block attached to a rattan frame and a blunt knife or 'bole'. The fibre thus gets separated from the pulp: it is hung on poles to dry, tied up in bundles, graded and packed in bales of 275 lbs. each. This method of isolating the fibre is now mostly replaced by machinery. There is much wastage in any case in the process of extracting the fibre. Each stem yields about 5 lbs. of fibre, the annual yield per acre being regarded as about a half ton on an average. The fibre strands are between 6 to 10 feet long and are somewhat flattened, the diameter being equal to that of linen. The ultimate fibres are from 0.08 to 0.12 inch long, taper gradually towards the ends and have large central cavities. The colour of the fibre is pale yellow to brown but, if carefully extracted, it may be nearly white. The fibre is lustrous, strong and tenacious and, being light, can float on water. It is very hygroscopic. The finest qualities are woven into muslins and other fabrics but the general use is in the manufacture of cordage which, on account of its lightness and great tensile strength, is much used for marine purposes. A small quantity is used for stuffing and brush-making. The refuse makes good raw material for paper. As manilla fibre varies considerably in quality, lustre, etc., the Philippine Government has introduced compulsory grading both for the fibre as well as for the hemp strips. Some of these grades are Extra Prime,

Prime, Superior Current, Good Current, Midway Current, Seconds, Brown, Damaged, Strings and Tow. There is a difference in price of at least £2 per ton between each of these grades, Extra Prime commanding the highest price. The total exports of manilla fibre from the Philippines is over a hundred thousand tons, half of which goes to the United Kingdom.

We have already described **Deccan hemp** as a fibre similar to jute.

Coir

Coir is the fibre obtained from the husks of coconuts or the fruits of the coconut palm **(Cocos nucifera)** cultivated extensively in India, Ceylon, Philippines, Malay and the tropics. The word coir is derived from the Malay word **Kayar**, meaning cord, from **Kayaru** twisted Coir is obtained by separating the fibre from the pith and rind of coconuts. It is estimated that over 2½ lakhs of persons are engaged in the manufacture of coir and coir goods in India, and that the husks of over 750 million nuts are used in the industry on the West Coast alone. The most important process is **retting:** the husks which should not be too dry are soaked in retting pits in saline backwaters, riverbanks and rarely in fresh water. The best coir of Anjengo in South India is made by placing the husks in a net made out of coir and kept floating for a few days· then they are covered over with cadjans and clay, and sunk. Sometimes they are buried in pits connected with the lagoons by means of canals or in field muds adjacent to the backwaters. The tide and ebb help to soften the coir. Fresh water retting does not separate the fibre from the pith completely and does not turn its colour to a golden yellow. The time required for retting varies from eight months to two years, though in some localities the retting period is very much shortened as in the East Godavery District: but stunted retting does not proudce a good fibre. After the husks are properly retted, they are removed from water, washed and taken to the husk-beating centres. Here they are beaten down on blocks of wood or stones

with small sticks or mallets. This separates the fibre from the pith and the rind which are well shaken out. It is then washed and spread out in the sun and beaten again, if necessary. A 'cleaner' is often used or the fibre is teazled by being thrown up and down between two sticks, an operation which not only removes any adhering particles of pith but also mixes the long and short fibres. There are factories which manufacture coir fibre for export: here, the dry husks are soaked in cement tanks for about 8 to 10 days and crushed, extracted and willowed by machinery. Coir fibre is either **bristle fibre**, stiff and hard, or **mattress fibre**, soft and pliable. About 1150 husks would yield one cwt. of bristle and two cwts. of mattress fibre. Fibre is converted into yarn by twisting, either as a cottage industry or by machinery. Usually one foot slivers are rolled out, other slivers being added as required and the spun yarn being held in position by the toes. The several ends are spliced together, thus producing long hanks of about 450 yards each and 2½ lbs. in weight. These are graded and made into bundles of one cwt. each and shipped in pressed bales. Inferior yarns are made up in bundles of 5 to 7 lbs. known as Dholls. Coir yarn is used in the manufacture of strings, ropes and cordage, mats and matting, or rugs and carpets. Coir fibre is also used for stuffing or for making brooms, brushes etc. The fibre is composed of a mass of very strong, elastic, reddish-brown filaments tapering towards the ends and about 6 to 13 inches long: these filaments are composed of fibro-vascular tissue consisting chiefly of very short, irregular, thickened bast fibres of uneven diameter. The fibre is very resistant to the action of water and, being light, can float on it.

CHAPTER III.

ANIMAL FIBRES

Wool

Wool may be defined as the outer covering or coat of sheep and certain other animals and is regarded as a fibre In so far as wool grows from the epidermis or outer skin, it may be classified as hair but it is difficult to determine at what point an animal fibre ceases to be hair and becomes wool. In primitive wild sheep, there are two coats, the undercoat being of fine wool and the outer coat of coarse hair. The difference in fact between wool and hair may be due to this fineness or coarseness—the flexibility. waviness and elasticity of wool, its crispness and curliness allowing it to felt in a compact mass as against hair which, due to its comparative smoothness and straightness, can be matted or entangled but will not cling to each other.

A fibre of wool, inspected under the microscope, resembles a serpent's skin. The overlapping scales of the cuticle give it a serrated or saw-like appearance and present innumerable little points which act like hooks They are very minute and range from 1200 to 3.000 per inch, the best quality wools having a much greater number than the inferior ones. These serratures fit into one another when wool is spun and help to bind the fibres together, just as the natural convolutions of the cotton fibre lend easily to the manufacture of cotton yarn. The quality of wool, its lustre, firmness, strength and fitting power depend upon the nature and compactness of these scales. Underneath the scales is the cortex, composed of a number of spindle-shaped cells whose density determines the elasticity of wool. The pith or core of the fibre may or may not be in the shape of a cavity or medulla. Wool varies very much in quality, denoted by length, fineness and softness of the fibre, from different breeds of sheep and different

parts of the same animal. The finest wools are of the merino type bred in Australia and South Africa and are known as **botany wools.** Argentine produces large quantities of cross bred wools of a lower type. India which has almost as many sheep as New Zealand, about 25 million, produces a poor clip and a poorer yield, our production per head averaging only about 2lbs. per head as against 6 and 7 lbs. elsewhere.

The quality of wool is determined by its **staple,** meaning the length of the individual fibre. Wools above $1\frac{1}{2}$ in. in length are considered long-stapled but some wools reach more than 5 inches. Long-stapled wools are used for the finest worsted yarn, the shorter fibres being carded and spun into 'noils' for making **woollen yarn.** When the latter is milled, the fibres become felted and lie in all directions, whereas in the case of **worsted yarn,** they are more or less parallel. Wool sheared from the sheep is better than that from the skins of slaughtered animals as these skins have to be soaked in lime or a solution of sodium sulphide for 'pulling' the wool which thereby becomes inferior. All fleeces represent one year's growth, the first wool of lamb being the finest, having no cut end. Wool from different parts of the fleece is sorted at the factories and though ample precautions are taken, the wool sorters are often subject to anthrax, a disease whose germs are carried in the impurities connected with wool. These impurities are often as high as 30 to 40% and may be suint or dried sweat, grease, vegetable matter like burrs, scales etc., dirt including faecal matter and traces of lime. Most of these impurities are got rid of in the process of scouring, teasing and deburring preliminary to manufacture.

The fibre of wool is capable of taking much more moisture than that of cotton without appearing damp. In fact the standard moisture content for wool is 18 per cent, compared to 11 per cent for silk and $8\frac{1}{2}$ for cotton. This moisture is lost on heating so that woollen fabrics appear to 'steam' when held before a fire. Wool is more readily injured by heat than cotton. Due to the outer covering of overlapping scales in the fibre, woollen garments have a

greater tendency to shrink on washing: this tendency is minimised by treatment with certain chlorine compounds in the so-called unshrinkable fabrics where chlorination has effected a considerable smoothing out of the scales, but the chlorine compound known as bleaching powder has a destructive action on wool and cannot be used as a bleaching agent, hydrogen peroxide or sulphur being therefore used. Wool being a much poorer conductor of heat than cotton, woollen garments are considerably warmer; wool is, like silk, a non-conductor of electricity. Chemically, wool is regarded as a **keratin** composed of the elements carbon, hydrogen, nitrogen, oxygen and sulphur The presence of sulphur helps to distinguish wool from all other fibres including silk. If wool is burnt, it resolves itself into ammonia gas (whence the characteristic odour of burning wool) and carbon 'beads' or 'remains': cotton does not smoulder or leave beads on burning. Wool has a direct affinity for all dyestuffs and can be dyed with all the direct cotton dyes as well as with acid and basic dyes, for which cotton has little or no affinity. When boiled in solutions of any of these dyes, the woollen fibre becomes permanently dyed and, unlike cotton, the colour will not wash out. Finally unlike cotton, wool yields no other bye-product except **lanoline** (which is the semi-solid purified wool-fat used for cosmetics and medicinal preparations), even the refuse and waste being re-used in the manufacturing processes.

After wool is sorted, scoured, dried, teased and deburred if necessary, it is ready for the various processes of manufacturing **woollens, worsteds or felts.** The main difference between woollens and worsteds lies in the preparation of the respective yarns, the fibres crossing and intercrossing in the case of the former and brought in a smooth and parallel relationship in the case of the latter. This is achieved by carding in one case, and combing in the other. In the case of woollens, further, the fibres may be a mixture of wool and non-wool but in the case of worsteds, it must be long wools. In the manufacture of felts, the fabric is not woven, the lap of required width and length be-

ing built up, sliver by sliver, on special frames hardened by the application of heat through steam and carefully brought in contact with a fulling or milling agent like soap, after which the fabric is continually hammered, the fibres thus becoming interlocked closer and closer together. There is no warp or weft for felts which are regarded as the oldest textile materials extant. For further information, the reader must refer to the book on "Wool" published in this series or to any advanced text book.

Hair

In the last section, we have learnt that it is difficult to demarcate between wool and hair. All animals, man included, are provided by nature with a protective covering in the shape of **hair**, wool or firs, and in so far as these all grow from the epidermis or outer skin, their nature like their functions may be regarded as similar. But their use by man as fibre depends mainly on their structure. We have seen that wool proper has an outer covering of serrated scales which help in spinning by binding together the individual fibres. In the case of most hairs, however, their smooth surface prevents their being clung together when spun. While sheep is the only animal which carries a fleece of wool only, there are certain animals which possess both wool and hair. Thus, the musk-ox has an undercoat of beautiful soft wool and an outer coat of strong hair. The camel, too, has two coats, one of wool and the other of hair. There are however animals whose hair can be regarded as wool and used as such: these are the **goat**, the **Llama** and the **Alpacca.** There are two wool-bearing goats, the **Angora** and the **Cashmere.** The hair of Angora is soft and silky and is known as **mohair.** The Cashmere goat has fine undergrowth of woolly hair used in the manufacture of shawls. The Llama of Peru bears very fine wool while the Alpacca of South America yields a black or dark brown fibre which is elastic, strong, lustrous and silky, and which weaves into a shining fabric known as **Alpacca.** Owing to the variation in their composition, these pseudo-wools possess more lustre than wool proper and their structural

differences influence the processes by which they are prepared or spun and the character of their yarns: but these differences are not fundamental.

Every hair grows from a **hair-follicle** which may be described as the tubular inpushing of the epidermis or outer skin into the dermis or true skin. The hair grows upwards from the bottom of the follicle by multiplication of the soft cells which become elongated and pigmented to form the fibrous substance of the hair-shaft. Externally, this fibrous substance is covered by a delicate layer of imbricated scales forming the **cuticle**. In many hairs, the central shaft has an axial substance, the **medulla**, which frequently contains minute air bubbles. It is the nature of the cuticle that mostly determines whether any given hair has textile or other value. From this point of view, the hairs of horses, cows, camels and rabbits are the most important. While the first named is employed in its natural form as an individual filament or **monofil**, the others are largely worked into felts, the hairs being compacted together because of the peculiarity of their structure which causes the imbrications of the surface. Horsehair is largely used in the upholstery industry along with flosses, wool flocks, and other short animal hairs and wastes. Camel hair, apart from felting, is also useful for making fine brushes though this camel hair is obtained from a species of squirrel and not from camels. In the last chapter we shall refer to hairs and bristles of certain animals used for brush-making. The tail-hairs of the elephant are sometimes plaited to form rings and bracelets. Human hair has very little utility value as a fibre. Besides individual hairs, the whole skins, hair and all, of certain animals like the beaver, opposum, fox, rabbit, squirrel, ermine, minx and even the leopard and tiger, form soft downy furs when dressed and dyed by the furriers and are used as such for a few purposes replacing manufactured textiles or leather.

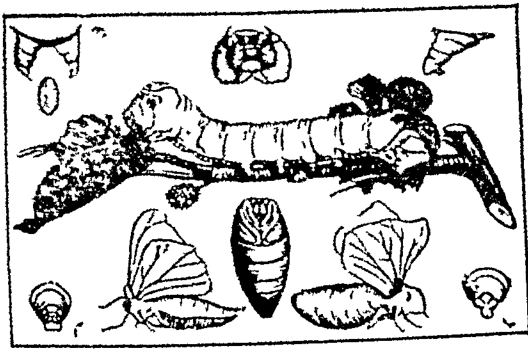
Silk

The word 'silk' represents the fibre formed by the solidification of the material excreted by the silk-worm, which

is the caterpillar stage of the silk moth. This moth, like the butterflies, passes through four distinct stages in its life-history. First there is the egg: this hatches into a larva or **caterpillar** which differs from the final winged adult in so many respects: the caterpillar next enters the grub or pupa stage known as the **chrysalis** when it remains quiescent for some length of time and finally emerges as a full grown **moth**. The full study of the different stages in the metamorphosis of silk moths has put the silk industry on a scientific basis and has enabled sericulturists to produce caterpillars and to induce them to weave **cocoons** under artificial conditions.

The sily worm, then, is a caterpillar or larva hatched out from the egg of the silk moth. It is found that this worm feeds voraciously on the leaves of the mulberry plant: there are some seventy thousand acres under mulberry in India. At the **filatures** which are the working places for reeling silk, the eggs are kept at a cool temperature till the mulberry plant begins to sprout leaves: they are then placed on trays in a room heated to about 70° to 80°F. The worms begin to hatch out in about three days and are enticed to climb through the meshes of fine silk network on to finely chopped fresh mulberry leaves. They are thus carried to the rearing room, each day's hatching being kept separate. The worms feed here ravenously on mulberry leaves till they reach maturity in between 32 to 38 days, and have to be safeguarded against diseases like diarrhoea, jaundice etc. During this period, the worms cast their skins four times and, when fully grown, they become restless and change colour. They are then taken to the cocoon room and placed near twigs or trellis work to which they cling by silken fluids emitted from their **spinnerets** in a continuous stream. They wriggle their bodies and wave their heads so that they become completely hidden inside the silken envelopes. While inside they continue to emit the threadlike fluid which continually becomes finer until they have spent themselves. Then they lie exhausted and pass into the chrysalis stage. The chrysalis can remain as such in a cool atmosphere for any length

of time but when removed to temperatures between 64° and 70°F it develops into a moth and emerges from the cocoon by exuding an alkaline fluid which softens the gum at the cocoon orifice. The following diagram shows the silk moths, silk worm etc.: the new born moth can be seen just emerging from the cocoon:—



At first the moth clings to its cocoon in a lifeless condition but soon it flaps its wings and dries itself. Very soon the male and female moths pair off after which the females are placed on special trays where they are allowed to lay between 20 to 60 eggs which are kept separate for breeding as moths; they are then taken to other trays where they lay over 200 eggs which are ear-marked for silk-rearing. The female moths which have no nutritional organs and which seem to live only for the purpose of perpetuating the species are then destroyed.

Those cocoons which are not intended for propagation are placed in an oven hot enough to stifle the chrysalis within them, after which they can be stored for any length of time. In hot climates, ovens are not required as the chrysalis can be stifled by the scorching heat of the sun. This is what is done by the native reelers. The cocoons are now dried and sorted and are ready for reeling. This reeling is not a difficult process, nature having taught the worm to move its head in a figure of 8 while spinning the cocoon—which makes the unwinding easy. Only the gum by which the cocoons are set hard must first be softened by immersion in hot water and the outer covering pulled

by means of a revolving brush. so that the connecting thread which binds their outer covering to the cocoon becomes broken, and, can be passed on to the reeling basin. In this basin, there is a tepid soap solution in which are placed the exact number of cocoons (between 3 to 20) required to produce the desired thickness or count of the silk yarn. The threads of all these are gathered and passed around a suitable contrivance which imparts a slight twist to the compound thread which is then passed through a drying medium to a reel. This reel revolves and unwinds the fibres from the cocoons. Great care is necessary as the threads might get damaged or lumped. After some unwinding, the fibres become finer so that the operative must keep an eye to the desired thickness of the yarn. Knotting is not necessary as the gum of the fibres allows sufficient cohesion to grip any added fibres. Skeins of silk are wound on reels of different diameters and in varying length, according to the district in which they are reeled. These skeins when exported are subjected to further treatment in what are known as silk throwing mills. Here, after the bales are opened and the skeins, books etc., are sorted, they are washed in order to soften the threads which are then wound on bobbins or are cleaned, doubled if necessary, and 'thrown' on to another set of reels which are then stored so as to set the twist and prevent any recoil. The operations of winding and throwing are done by machinery There are certain original reels known in the trade as "native reels" prepared under primitive conditions and offered in the Asiatic countries: these are re-reeled at the filatures and are known as re-reels.

It will be evident that there will be some certain waste (chasam) in the reeling and throwing processes: also there will be cocoons which cannot be completely unwound. There is, for instance, the *eri* silk worm common in many parts of India which feeds not on the mulberry but on the castor plant and whose asymmetrical cocoons cannot be reeled at all. All these are converted into silk yarn at the special silk spinning mills and yield what is known as spun silk. For the special processes involved, separate text

books, or the book on Silk published in this Series, may be consulted. It remains merely to be mentioned that apart from these silk-worms, there are other silk worms especially the **tasar** silk worm of Bihar and Orissa or the **muga** of Assam from which separate qualities of silk yarn known as Tussore or Tussah, Shantung etc. are produced which are somewhat inferior. Silk worms are found in China, Japan, France, Italy, Uganda and many other places but the best silk is yielded by the silk worm **(Bombyx mori)** above described which feeds on the mulberry, preferably the white variety. Though the Mysore silk industry accounts for about two-fifths of the total silk output of India, Kashmir has an old-established industry which is a state monopoly but the silk moths there are **uni-voltine** (producing only once a year), grown from seed imported annually from the Continent. Bengal too has about 25,000 acres under mulberry and the silk worms there are **multi-voltine.** A rough estimate gives the annual production in India of cocoons at about 30 million lbs. and of reeled silk at about 2 million lbs. There is a large export of raw silk and silk waste (chasam) from this country. The highest production is in Japan with about 90 million lbs: then comes Italy, Korea, Russia, Greece, Turkey, India and Bulgaria in that order.

Raw silk loses about 25 per cent of its weight in degumming and then the single lustrous filaments appear under the miscroscope like rods of glass. Wild silk is much broader and coarser than cultivated silk and their cross sections are flattenned and show distinct fibrils. The viscous fluid exuded from the glands of the silk worms comes out from two channels or spinnerets situated in the head of the worm and so disposed that the issuing filaments **(brins)** run parallel with only a minute distance between them. They solidify in contact with the atmosphere. These filaments are **'fibroin'** and are consolidated by the secretion of silk-glue or **'sericin'** from two other glands: these double filaments can be identified under the microscope: their length in the cocoon varies between 3000 and 4000 yards of which from 600 to 1200 yards can be reeled.

the rest being used for spun silk; the diameter ranges from 0.019 mm. to 9.030 mm. which shows an extreme variety of thickness.

Silk is a bad conductor of electricity and, therefore, is used for insulating electric cables: it can be easily electrified by rubbing. Silk is also a bad conductor of heat and it is therefore used for making warm clothing. Silk is very hygroscopic, even more so than wool and will absorb more than 25 per cent moisture without feeling damp. Its normal moisture content is only 11%. The fibre substance, fibroin, has many properties in common with wool and other animal fibres. Thus, it is not easily inflammable and gives the burnt hair smell on ignition. It is dissolved by boiling alkalies but not so readily as wool and can withstand boiling in dilute acids. It can be dyed a bright yellow like wool with boiling dilute nitric acid. Silk absorbs acids from their solutions in water and therefore weak acetic and tartaric acids are applied to silk to produce the **'scroop'**, which means the peculiar rustling sound noticed when folds of silk are rubbed together. Discharged unweighted silk does not crease easily. Silk can be readily dyed with any kind of dyestuff. Silk being a very absorbent fibre, the softness and lustre of silk goods can be easily affected during washing, dyeing etc. by impurities or dissolved substances in the water: the water therefore should be as soft as possible. Silk can be distinguished from other animal fibres by giving no colour when boiled with a weak alkaline solution of lead acetate: wool, etc. will turn brown or black. Silk can be distinguished from rayon by boiling with a weak solution of an acid dye and a drop of acid: true silks will be deeply dyed while the rayon will be merely stained and can be washed back. This test can be easily performed with diluted red ink. Silk can be bleached by hydrogen or sodium peroxide.

Mathews in his book on Textile Fibres gives the chemical composition of silk as: water 12.5%, sericin 22.58%, fats 0.14%, fibroin 63.10%, resins 0.56%, mineral matter 1.12%; but this composition is not constant. Fibroin and sericin are both proteins composed of carbon, hydrogen,

nitrogen and oxygen. A chemical analysis of mulberry leaves shows a surprising resemblance to that of pure silk in possessing elements in similar proportions.

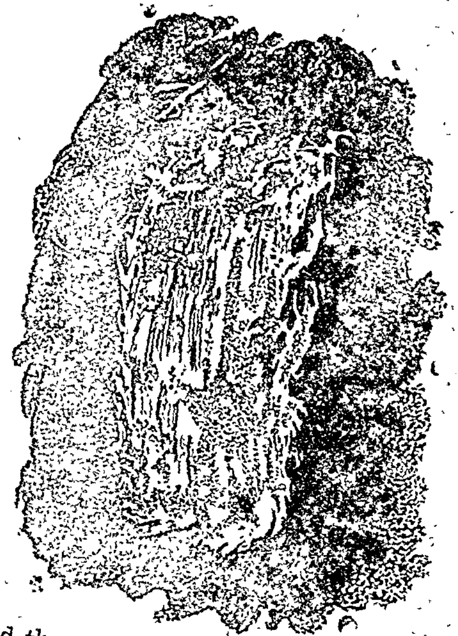
Silk is prized for its agreeable lustre, softness and relative durability. The various kinds of silk threads have received technical names with which we are not concerned here and can be woven into fabrics of beautiful designs and patterns. The Georgettes, Crepe de Chines, Taffetas and so on—all familiar words, denote the type of exquisite fabrics into which silk fibres can be woven. Silk is also used in combination with other textile fibres to produce variegated fabrics, and in the hosiery and knitting trade it cannot be equalled. Though rayon fibres have in recent years been so perfected that in many instances they have superior utility and value to natural silk, 'silk is and will remain silk after all'.

CHAPTER IV

MINERAL FIBRES

Asbestos

The name 'Asbestos' is derived from a similar Greek word meaning unquenchable, indestructible or eternal and is given to a group of minerals which are both crystalline and fibrous. This group comprises **anthophyllite** (which is unimportant), **amphibole** and **serpentine**. There are five varieties of amphiboles which are silicates of lime and

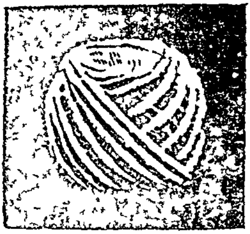


magnesia and the most important of which is blue asbestos or **(crocidolite)** found in South Africa and Australia. The great bulk of commercial asbestos is however derived from **chrysotile**, which is a hydrous silicate of magnesia and

which occurs in narrow veins traversing the serpentine rocks as a mass of fine silky crystals. These crystals can be easily separated into fine, white, silky, flexible fibres A lump of crude asbestos is shown above.

Crude asbestos when mined and 'cobbed' (that is, separated from adherent rocks) is first sorted: then, the blocks are crushed and opened by special machines; here the long fibres become separated from the short ones and other rocky material. The long fibres are passed on to the carding and condensing machines where they become condensed and are folded in cans: they are then passed to the spinning and doubling departments for receiving the twist before being sent to the weaving machines. Asbestos fibre resembles fine polished wire devoid of any serrations which makes spinning difficult; but once spun it can be woven into the finest fabrics like wool, flax or silk. Under the microscope, it is one of the most delicate fibres, one strand being capable of being spun to weigh less than an ounce to 100 yds. of length. It can be woven into very light cloth, weighing only a few ounces to the square yard. To be of commercial value, asbestos must possess length and fineness of fibre together with infusibility, toughness, high tensile strength and flexibility. Asbestos is a mineral which is unaffected by the fiercest fire or the strongest acid—which accounts for the fact that, while the hardest rocks have crumbled away from the earth's crust, asbestos though light and feathery has survived the ravages of time. It is this property of durability even under the most adverse conditions that accounts for the use of asbestos materials, paints and compositions for fire-proofing, insulation etc. The ancients were not unacquainted with the properties of asbestos, as is shown by their use of perpetual lamp wicks, asbestos shrouds etc.

We have seen that the long fibres of asbestos can be carded and spun into yarns—a ball of which is illustrated below:—



The spinning is sometimes done in conjunction with cotton or other fibre or brass or copper wire. The yarns are woven into fabrics of varying weights, thickness and densities to suit various industrial requirements. Some of the principal uses are for drop curtains in theatres where fire-proof curtains are legislatively compulsory, for fire-proof wall-linings and for boiler pipe-packing. When spun with wire, it is used as brake-linings; when impregnated with graphite and greases, it is used for steam and pump-packings. Ropes, cords and threads are twined for various purposes: thus asbestos thread is used for sewing materials exposed to heat or for suspending metals and crucibles in contact with fire and asbestos ropes for making rope ladders for fire escapes. Asbestos products are also used for insulating electric conductors. Short fibres which are useless for spinning are used for felting or are mixed with cement for moulding into mill-board, roofing sheets, tiles etc. Asbestos sheets, apart from being fire resistant also deaden sound and are therefore employed with marked effect for fashioning ceiling panels. Being fire-proof, such panels are now almost universally used in shipbuilding. There are many recorded instances where asbestos ceilings, wall-boards or shingles have helped to check the spread of dangerous fires especially in hotels and theatres, and even the use of asbestos paints on wood work is reported to keep it uninjured by flames. In the Burlington hotel fire, the asbestos ceiling is said to have checked its ravages and, though the coating of paint on the ceiling was burnt off, the ceiling was left intact in its natural whiteness except where blackened by smoke. History

20 having for instance as fine a diameter as .036 inches and still finer wires being drawn for special purposes like in the manufacture of special needles for threading pearls. As copper, its alloys and gold can be easily beaten or drawn out, samples of brass wire over 2000 years old have been discovered. These may have been made by passing metal through the tapered hole of a drawplate, though the invention of modern wire-drawing through a drawplate is assigned to the fourteenth century. Then, the workmen were said to have pulled the wire through a tapered hole in the plate by attaching its end to a belt around their waists and stepping backwards away from the drawplate. When the rolling of bars came into vogue, wrought iron was rolled for wire-drawing into rods of about $\frac{1}{4}$ in. in diameter but the introduction of mild steel has changed the character of this industry. Now, rolled rods of 1/5 in. or thicker are sent from the steel mills to the wire work. Here, they are thoroughly cleaned and scaled by immersion in dilute hydrochloric acid. They are then drawn either by the dry or by the wet method. In the former method, the wire passes from the swift or reel through a soap box which contains hard dried olive oil soap as a lubricant and thence through the small conical perforations of the dies on to the wire-winding blocks. In the wet method, the rods are first coated with a thin film of copper. Wire is now drawn continuously from rods of steel, copper, brass and other metals—the only difference with regard to different metals being in the methods of cleaning and annealing. A metal rod of say No. 5 gauge (.212 inch) weighing 160 lbs. will be a quarter mile long: when drawn to No. 10 gauge (.128), its length increases three times and when drawn to No. 30 gauge (.0124), it has a length of about 70 miles, having increased to about 280 times. The tensile strength also increases as the wire in being drawn through the draw-plate is subjected to enormous pressures.

CHAPTER V.

OTHER FIBRES

Rayon

The word 'rayon' denotes **artificial silk.** Various attempts have been made in the past to invent a substitute for the flossy and lustrous fibres of natural silk. About 200 years ago, a French Scientist, Reaumur, suggested that as silk was nothing else but hardened varnish, it should not be impossible to draw out certain varnishes into spinnable threads resembling silk. It was however not till the year 1885 that cotton cellulose was successfully squirted through minute holes for making filaments for electric lamps; and, a few years later, Count Henri de Chardonnet produced actual rayon yarns, wove them into garments and exhibited them at Paris. His first idea was, however, to use mulberry leaves (on which the silk worms fed) as the raw material for his fibre: but he soon discarded this for cotton and other vegetable substances. His process is now known as the Cellulose Nitrate or Chardonnet process. About ten years later, a new process was developed known as the Cuprammonium process, followed soon after by the Viscose process and finally by the Cellulose Acetate process. There are thus four methods of making artificial silk—the basis of manufacture for all of which is cellulose obtained either from cotton linters or waste or from wood pulp made from soft seasoned wood like spruce, fir and pine, obtained chiefly from Canada, Sweden, Norway and Finland. Cotton raw is no doubt easier to convert into cellulose and the thread obtained is stronger and superior but the cost is comparatively greater than for conversion of wood into degummed pulp. Whether it is cotton or wood the main principle of rayon manufacture lies in their formation into cellulose in the shape of thin sheets and in the

dissolution of this cellulose through chemicals into a viscous spinning solution which can be converted into fine filaments by forcing it through minute orifices in spinnerets; these filaments are then passed through a coagulating medium in which the chemicals which hold the cellulose in solution are separated so as to form continuous threads. In the following diagram, the first figure shows cotton-linters, the second wood chips ready for conversion into cellulose and the third, either material made up as thin sheets of purified pulp:—

At present, Viscose rayon forms over 80 per cent of the world's production, Cellulose Acetate comes next, then Cuprammonium and finally Cellulose Nitrate rayons. We shall briefly describe each of these, referring the reader to the book on Silk published in this Series for fuller information.

For **Viscose rayon**, wood pulp cellulose is almost invariably used. The wood is freed from non-cellulose matter, such as lignin, resin and gums, and from knots, and is converted into pulp which is pressed into somewhat corrugated sheets resembling very brittle cardboard as shown in the illustration. It may be mentioned here that the conversion of wood or cotton into celludose sheets and the manufacture of fibre from these sheets are two entirely different processes, there being separate factories for each at different centres. Now, as soon as wood-pulp sheets arrive at the rayon works, they are dried and cut up into smaller pieces and steeped in specially constructed tanks containing a solution of about 17½ per cent caustic soda.

When thoroughly saturated, the caustic is run off and the sheets pressed into **alkali cellulose pulp.** This is now disintegrated, kneaded and made into crumbs in special machines, and the resulting white flocks are allowed to mature for about 72 hours at 25°C. The next process is churning in which the flocks are treated with carbon bisulphide to form **cellulose xanthate** which is mixed with a 3 to 4 per cent solution of caustic soda to produce **viscose.** This viscose is ripened for four or five days and filtered, any air bubbles being abstracted by vacuum. The material is now ready for spinning. The viscose is forced by pumps through spinnerets or jets into a spinning bath containing usually sulphuric acid, sodium sulphate and glucose. This bath coagulates the filaments which are wound and reeled into hanks. The spinning is done either on the centrifugal system (pot spinning) or on the bobbin system. These hanks are successively washed, stretched and stored, desulphurised by treatment with one per cent sodium sulphide, washed, bleached (if required), scoured, washed, hydro-extracted, dried and conditioned and sorted into grades. Viscose rayon can now be made with any required lustre and of any desired fineness: it has a great attraction for moisture and dyestuffs. To provide lighter garments, cellulose rayon is now also offered as hollow filaments (known as Celta) with gas or air imprisoned within their walls.

Cellulose Acetate rayon, made famous under the registered trade-name **Celanese,** is generally made from cotton, though very pure wood pulp can be used. Purified cotton waste or linters which are generally too short in fibre for other manufacturing processes and from which wax, fat, colouring matter etc. are extracted by bleaching, are heated with a mixture of acetic acid anhydride in the presence of a catalyst (usually sulphuric acid or zinc oxide) to form a **cellulose acetate** which is soluble in chloroform. This is mixed and heated with a further quantity of acetic acid and water, precipitated and dried: it is then dissolved in acetone, filtered, de-aerated and spun, either wet or dry. In the former case, it is spun into baths of oils, hydrocar-

bons, or salt solutions, sometimes by the stretch spinning methods and the threads are collected on bobbins, washed, dried, twisted, reeled etc. In the latter case, the thread is coagulated by the evaporation of the acetone and is twisted at the spinning frame by cap or centrifugal spinning. Cellulose Acetate rayon has a lower specific gravity than other artificial silks and is warmer and somewhat harsher. It is also very elastic and possesses greater insulating power but less capacity for moisture. Special ranges of dyestuffs become necessary because of its peculiar affinity for dyes. These special properties may be due partly to the fact that while the other rayons start and finish as cellulose, Cellulose Acetate starts as a cellulose but finishes as a chemical compound of cellulose and acetic acid. In addition to Celanese, there are other cellulose acetate silks on the market under different trade names.

Cuprammonium or Cupra rayon is generally produced from purified linters or cotton waste, though specially purified wood pulp is used to some extent. The basic principle of this process is that crystalline blue copper sulphate, with the aid of caustic soda and ammonia, can be transformed into a liquid which dissolves cellulose. The cellulose is first machine-ground into a fine pulp, to make it more readily soluble. This pulp is mixed with copper hydroxide in a disintegrating machine and then filtered under heavy pressure. The press cake, so formed, is dissolved in concentrated ammonia in a stirring vessel and the solution which is deep blue in colour and of the consistency of honey is prepared for spinning by passing it several times through filter presses to storage tanks and then submitting it to vacuum. The solution is now conducted to the spinning machines for wet spinning and passed through the orifices of the spinnerets into a sulphuric acid or caustic soda coagulating bath, the thread being usually stretched in its passage from jet to bobbin and bleached, soaped and dried before twisting. This makes cuprammonium yarns of very fine filaments (even finer than 1 denier) and consequently of good lustre and soft handle.

Cellulose Nitrate rayon, perfected as we have seen by Chardonnet, is also made from cotton. Purified linters or waste is nitrated by a mixture of nitric and sulphuric acids to form **nitro-cellulose** (gun cotton or pyroxylin). This is washed, bleached, pulped and dissolved after drying in a mixture of ether and alcohol to form a viscous spinning solution (**collodion**) which is filtered, de-aerated and spun. Dry spinning is employed usually on to bobbins and, before complete solidification, the filaments may be drawn out and made finer. As the alcohol and ether evaporate, the thread coagulates and hardens. In wet spinning, the filaments are squeezed out into a water or salt bath which removes the alcohol and ether from the collodion. The threads are now reeled into hanks and denitrated by mixed solution of calcium, sodium or ammonium hydrosulphides. They are then washed, bleached, soaped and dried. In this method, it is possible to control the shape and surface formation of the filaments and thus to vary their lustre, handle and covering power. The chief disadvantage for this class of rayon is that denitration causes considerable loss in weight (about one-third) accompanied by greatly reduced strength of the thread especially when wet as its resistance to water is largely decreased.

There are modifications of the final rayon fibre for certain purposes. Thus "delustred rayon" is produced by special treatment for certain textile uses. "Staple fibre rayon" is produced by cutting continuous rayon filaments into definite lengths to correspond with the length of staple of cotton or wool, the yarns being then spun by a true spinning process.

Artificial silk can be easily distinguished from pure silk by its more brilliant and more metallic or glossy lustre. The modern tendency is however, by using finer filaments, to produce a yarn more resembling silk. Ordinary rayon has a harsher, stiffer and colder feel than real silk and is more easily creased. All artificial silks lose a great deal of their strength when wet and require careful handling. They recover their strength on drying. A portion of the lustre becomes permanently destroyed when boiled in

water or soap solutions for sometime unlike natural silk. A thread of artificial silk when wetted under tension, say by laying it across the tongue, will show a reduction of strength which real silk does not. Also on burning, all rayon fibres do not like silk emit a smell of burnt hair. All such rayons except Cellulose Acetate burn very quickly, like cotton, with little odour or ash, and Cellulose Acetate burns with difficulty, a thread when ignited forming hot molten globules at the charred ends, somewhat like burnt wool or silk but emitting a characteristic smell.

General qualities of rayon contain from 2 to $2\frac{1}{2}$ turns per inch. They are not reeled in fixed standard lengths but in such lengths that the number of hanks per pound or Kilo is the same. This method varies with the maker but English hanks are made up in bundles of 10 lbs. weight with approximately 100 hanks to the bundle. The method of "counting" is the metric **denier** as in silk, the basis being the weight in half decigrams of 450 meters of yarn. For convenience, this weight is taken instead in grams of 9000 metres.

Rayon fibre is not necessarily a substitute for silk but has its own distinctive uses, either alone or in conjunction with other fibres, for a great variety of fabrics and purposes. It is thus combined with silk, cotton, wool and linen, apart from being used for turning out "all-rayon" fabrics and knitted wear. Special machinery is necessary for weaving as the yarns, being uniform in thickness and appearance, are so clear and smooth that any irregularity in the woven fabric will show out as a defect. Apart from textiles, Viscose rayon is used in place of ramie as the foundation for incandescent gas mantles, and Cellulose Acetate for insulating electric wires. A film of rayon can be spread and engraved on rollers into artificial tulle (or network fabric) or, as cellophane, can be used for transparent wrapping. Rayon is also now used in the manufacture of artificial leather, or artificial feathers, flowers etc.

The manufacture and consumption of rayon yarns and fabrics in the United States which rank first in the world

in this line have increased phenomenally in recent years. From·487 million lbs. in 1940 the latest available figures for 1944 show a jump to 705 million lbs. In India our imports of rayon yarn and piecegoods have also increased to about 50 million lbs: we do not yet manufacture rayon yarn (or pulp for it) in India though there are sources available for spruce, fir and other suitable soft timbers in and near Kashmir.

Silk Cotton

Silk cotton is the name applied to the down or floss attached sometimes to the seeds and sometimes to the inner walls of the capsules of certain plants belonging mostly to the **Bombax** family, the chief of which is **Kapok**. The real Kapok is a large forest tree occurring in India, Ceylon, Malay, Philippines and Java. In the last named country it is regularly cultivated. There are abount 12 different species. The tree begins to bear when five to seven years old and continues to yield for 50 years or more. On ripening the fruits become brownish and begin to open: they are then gathered by means of hooked bamboos and exposed to the sun on a cemented or clean floor for complete ripening. The fibre and seeds are picked out by manual labour and again dried in the sun. No real ginning is necessary as the fibre can come out of the seeds on beating with sticks or through simple machines. The Kapok fibre is packed lightly in bales of 80 lbs. each, as, being weak and buoyant, it is liable to be broken or damaged if pressed hard.

The fibre consists of pale yellowish silky lustrous hairs which, like cotton, are unicellular. The cell-wall being thin, the fibre is not as strong or durable. The hairs are straight and smooth and do not possess the twist of cotton hairs and cannot therefore be spun or employed for manufacturing textiles, unless chemically treated or mixed with cotton. But, on account of its lightness and resiliency, Kapok makes an excellent substitute for hair or feathers for stuffing mattresses, pillows and similar articles. The cells of Kapok are full of air which makes it non-absorbent,

moisture-proof and buoyant: these qualities render it fit for use in temperature insulation or in the manufacture of buoys, life-belts, water-wings or bathing suits, Kapok being seven times lighter than cork. Kapok is much fancied in the United States which import upto about 10,000 tons per annum. There are plants other than the silk-cotton which yield flosses somewhat similar but inferior to Kapok; among these, we may include the Indian wild milky **Akra** which bears the floss on the inside of its capsules. This floss is very silky and lustrous but there is no commercial exploitation.

Ramie

In this group, we have to consider three separate fibres known as **Ramie, Rhea** and **China grass** which are closely allied to one another. All these are derived from the stems of different species of **Bochmeria**—a plant belonging to the **nettle** family but devoid of stings. The true China grass is **B. Nivea** whil• ramie of the Malay archipelago and rhea of Assam belong to different varieties (usually identified as **tenacissima**), which are more robust and have larger leaves, green on both sides. The leaves of the former on the other hand have their backs clothed with a downy substance and are silvery in appearance. These plants are often found wild in India, are easy to cultivate, and have been introduced into all the other continents. The chief cultivation is however in China and Formosa. The plants attain a height of 3 to 8 feet. The stems when ripe are cut down but are not retted. After the leaves, etc. are removed, the outer bark and the layers of fibre are stripped off in the form of ribbons. These contain a quantity of very adhesive gum, and degumming is indeed a very tedious process. The Chinese remove the bark and as much of the gum as possible before the plant has dried. Many decorticators have been invented for facilitating this process, the Govt. of India as early as 1869, having offered a prize of £5000 to the inventor of a suitable machine. Even then much headway has not been made and stripping continues to remain a tedious and expensive manual

operation and only a few pounds can be stripped per day. Degumming is generally not done in China but is subsequently undertaken in the importing countries by immersion in a caustic soda solution and boiling in closed vessels. The degummed fibre or fillasse is then washed out and laid on perforated plates to dry. It is softened by being passed through machines fitted with fluted rollers: it is thereafter subjected to the operations of dressing, roving, wet spinning and doubling: the twisted yarn so obtained is passed through a flame to remove superfluous hairs. The Chinese produce the fibre by hand and use it as substitute for silk. Ramie fibre is one of the strongest known: it is durable and is less affected by moisture than any other fibre but is not elastic. It has a brilliant silky lustre, can be easily dyed and is exceptionally long. The ultimate fibres are themselves 3 to 16 inches long with a diameter twice the size of cotton fibre. They are thick-walled, have well-marked cavities, and bear longitudinal and transverse markings. Ramie has a tendency to cling to rollers in spinning and therefore requires special machinery. It is used in China for making "grass-cloths" and can be woven into various kinds of fabrics like lace, curtains, underwear, tablecloths, plush, carpets, etc. It can also be combined with wool and other fibres for weaving special fabrics. But its chief use is in the manufacture of gas-mantles for which it is specially adapted. Though the plants can be grown easily and yield about half a ton of fibre per acre, the difficulty of extracting the fibre has hindered the expansion of the ramie industry.

Nettle Fibres

The ordinary stinging nettle yields a fibre which was used in the continent before the introduction of cotton for manufacturing textiles. There are other plants also of the nettle family which yield useful fibres. Two of them grow in India but are not much exploited. From the "Nilgiri nettle", a long soft silky fibre is obtained almost like ramie and from the 'ban rhea' which grows wild on waste lands

and which has less gummy matter than ramie, a similar fibre can be extracted with ease.

Banana Fibre

We have seen in the second chapter that manilla hemp is derived from the sheathing leaf-stalks of a plant which is very much allied to the **banana.** The leaf-stalks of the latter too yield a fibre but, as it is much weaker than the Manilla, it cannot be satisfactorily used for cordage; strips of these stalks are often used as **binders** by agriculturists. One stump after fruiting can yield about 1½ lbs. of fibre. The wild plantain yields a much better fibre. The discarded stems of plantain bushes have been recommended for use in paper-making after cleaning, drying and crushing but, as about 132 tons would be required to make one ton of paper, the proposition does not appear to be economic.

Pineapple Fibre

Though **pineapples** are grown all over the tropics including India, the leaves are not used for extracting fibre except in the Philippines and Formosa where they are cultivated for fibre, preferably in the shed, and not for fruit. In the former country, the successive layers of fibre are isolated from the leaves by scraping with a blunt iron, in the latter by means of a piece of a broken pot. About 50 lbs. of fibre can be had from one ton of leaves. The fibre is soft, fine, strong, lustrous and white and is used for making beautiful silky fabrics. A portion of the produce of Formosa is exported to China for making superior grass-cloths. The leaves of pineapple bushes which have fruited yield an inferior fibre and are therefore recommended as raw material for paper-making.

Palm Fibres

There are various members of the palm family which yield useful fibres. We have already referred to the coir of the coconut palm. There are at least two other palms which grow largely in India and the tropics whose sheathing leaf-stalks yield useful fibres. These are palmyrah

and Kitul. **Palmyrah fibre** is strong, wiry and about 2 feet long. **Kitul fibre** is much finer, softer and more pliable, resembling horse-hair. Small quantities of both are exported by us to England. The **Oil-palm** which grows in West Africa bears leaflets which yield a pale yellowish-green, strong fibre but the fibre is difficult to extract and is therefore used locally for making fishing lines or fine cordage. The **Raphia** palms of Africa and Madagascar yield **Raffia** or **Bass** which are fibrous straw-coloured strips or ribbons about 3 or 4 feet long combed out from the leaf-cuticles and used for plaiting or tying up plants: there is a considerable export from Madagascar. There are other species of Raphia palms in Africa which yield a fibre comparable to the piassawa of Brazil. Among these may be mentioned the "**Wine palm**": its sheathing leaf-bases are cut and immersed in water for a few days and the strands of fibre are hackled out by drawing through nailed boards or split bamboos. This fibre is very stiff and wiry and is used for making brooms, brushes or baskets. **Piassawa** proper which is also used for making brooms and brushes is the name applied to the elastic wiry filaments which remain attached to the stems of certain palms in Brazil after the sheathing leaves have fallen off. A portion of the dilated leaf-stalk remains on the stem and when its softer tissue decays and falls off, the piassawa, bending downwards when mature, give the palms their characteristic appearance. There are two varieties, the **Bahia** piassawa, chocolate coloured and flexible, from which brushes for road-sweeping machines are made, and the **Para** piassawa, strong and black, from which brushes for grooming horses are prepared. There is a shorter brown Piassawa fibre produced from a Madagascar palm.

Crin Vegetal

This is the name given to the fibre used for stuffing upholstery and produced from the leaves of dwarf fan palms growing wild in Southern Europe and Northern Africa. The leaves are moistened and subjected to the action of rapidly revolving spiked drums. Short coarse

fibres thus obtained are twisted into ropes and left for a few weeks. The ropes are then untwisted so that the fibres receive a crinkled appearance, hence the name 'vegetable curled hair'. It is eitheir used in its natural colour or dyed black to simulate horse-hair.

Whisks

A whisk means a small bunch of anything fibrous used as a brush. In the vegetable kingdom, we come across certain fibrous tissues which can be bunched together to form a brush. Thus in India we use whisks made out of straw or much beaten branches of certain trees. In Italy and Hungary the roots of a certain grass are used. The Mexican whisk is nothing but the roots of Zacaton grass; these roots, about a foot long, are wavy and flexible and can be easily bleached. They are exported to the Continent for making carpet brooms or cloth brushes but the fibre is somewhat brittle. The Italian whisk is the tuft of the stem, with its bunch of stiff stout stalks about 2 feet long of broom corn which is a millet allied to Sorghum or Jawar. It is cultivated in America and New South Wales. Whisk brushes used by hair-dressers or drapers are made from these whisks.

CHAPTER VI

MISCELLANEOUS

Elastic Fibre

Rubber, which is the coagulated latex drawn from the bark of certain trees, has the property of elasticity. This property is availed of in the manufacture of **elastic thread** which is made of cut rubber yarns woven with fine cotton, silk or worsted yarn. The rubber yarn represents one of the highest classes of rubber goods, and, as it must stretch if properly made to seven times its length without breaking, the finest quality of raw rubber must be used. Originally, the threads were cut with a knife from rubber sheets or were produced by forcing a thick paste of rubber and naphtha through apertures in an iron plate and then evaporating the naphtha upon a French chalked surface. The discovery of vulcanisation, however, soon altered these primitive methods and now the production of elastic thread is a very technical process, briefly as follows. Raw rubber is dissolved with sulphur in coal-tar naphtha and is calendered to a thin and regular sheet on to cloth. This is then tightly wrapped in layers of cloth and vulcanised in steam in the form of a roll. It is then unrolled from the cloth, pasted over with a solution of shellac in wood naphtha and tightly rolled upon a drum. The shellac causes the rubber to adhere closely and become a firm cylindrical block in which state it is taken to the lathes where, by means of rapidly moving knives, it is cut into threads which are now of the length of the original sheets, about sixty-five yards long. These threads are then boiled in a solution of caustic soda, in order to remove the shellac and the excess of sulphur if any. It is then well washed in water, dried in a warm room and stored in a dark place. The threads are made in a variety of sizes or counts and can be pro-

duced down to .008 in. diameter. They are free from mineral matter and translucent or almost transparent. If not properly vulcanised they gradually lose strength and get rotten. Elastic thread becomes hard and brittle through oxidation or constant changes of temperature like the warmth of the human body: usually therefore it is covered by any required type of fine cotton, silk or worsted yarn. Extruded threads of a mixture of rubber and cellulose are also made in a similar fashion.

Special Fibres

In addition to the various well-known fibres so far described, there are special fibres made and used for producing novel blends, special effects or decorative purposes. Thus, apart from feathers and furs or hairs of pigs and other animals, fibres or filaments are made by cutting transparent **paper or cellophane.** They are shiny and may be cut to less than .001 in. in thickness and 0.2 in. in width. But like artificial silk, other artificial fibres are produced and used specially in Germany and Italy as substitutes for cotton and wool. Thus, new wool-like types of artificial fibre include such patent names as Artilama, Vistra XTH Lanusa, Woolstra, Cisalfa, Cuprama, Argona and others. They are produced or treated so that they will take acid wool dyes and possess resilience or crease resistance which is obtained by synthetic resin treatment; they are sometimes delustred by roughening or pigments so as to possess a wooly appearance and cling: they do not however have the milling power inherent in the scaly surface of feltable animal fibres. Ramie is used in wool blends to some extent but is more costly. As regards **artificial cotton,** hemp or flax is 'cottonised' by mechanical or chemical treatment, so that a short staple fine fibre capable of being spun more cheaply than flax is produced suitable for fabrics, which would possess linen properties, lustre and absorbency. Another treated fibre is **Xbred** which is used in blends for socks and carpets but it will not stand carbonising. A Russian bast fibre **Kanaf,** nettle fibre or milkweed, is somewhat similar. **Crinol** is artificial horsehair made from

special mixtures through extrusion and can be pigmented or metallised to simulate tinsel. **Tinsel** yarns are usually metal ribbons wrapped round silk or cotton yarn cores. These may be gold or silver coloured though not made from these precious metals but from burnished brass, copper or tin and may be without any core—as for instance the wiry thin lustrous metallic strips used for adorning garlands or bouquets in India.

Plastic Fibres

The modern development of plastics, to which subject a special book is devoted in this Series, has led to the production, especially in America, of plastic filaments and yarns by extrusion from some plastic material or by coating cotton, rayon and other yarns with some form of plastic. Thus **'Nylon'** from which ladderless stockings and gossamer lingerie as well as tennis gut and surgical sutures are made is prepared from coal, air and water, the threads being drawn out from a molten mass so that the long molecules of protein exert attractive forces on one another making the filaments very strong and durable. Nylon fibres are also used as bristles for various kinds of domestic and industrial brushes which, being resistant to chemicals, are long lasting. Another plastic filament **Saran,** which has a petroleum brine and chloride base is used for making hard-wearing and silky upholstery cloth which is difficult to stain. **Vinyon,** a plastic fibre from acetyline, is used for weaving ties, gloves, filter and screen cloths. **Aralac** prepared from casein is mixed with other yarns and used in the clothing trade. Cotton, rayon and other fibres coated with a plastic yield **Plexon yarns,** which can be turned out into any shape and colour and the cloth from which, because of the coating, becomes proof against dampness, vermins, fires, acids, perspiration etc. It is not unlikely that in this Plastic Age, we shall be soon discarding our familiar fibres in substitution for a new, attractive, cheap, and durable, synthetic product.

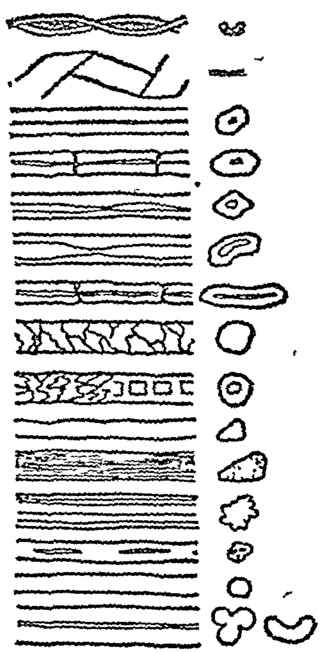
Analysis of Fibres

All fibres intended for use in the textile industry must be specially tested and for this purpose specialised knowledge is necessary. Chemical examination of fibres is qualitative and may be applied to any fibre. This is based on the original chemical composition of the fibre concerned. Animal fibres are composed of nitrogenous colloids namely albumen, fibrines and gelatines. Vegetable fibres, on the other hand, are celluloses and derivatives of celluloses, fats and waxes. This broad distinction between the two is evident in their relationship to alkalis. While the vegetable group is extraordinarily resistant to the action of alkalis, the animal fibres become resolved and finally dissolved by them. Thus, with hot caustic soda or caustic potash both silk and wool become dissolved, a few drops of lead acetate also turning the wool into a black precipitate. Cotton becomes completely decomposed (and forms a powder on drying) when immersed in strong hydrochloric or nitric acid. With dilute sulphuric acid it acquires a blue stain. Mercerised cotton can be chemically distinguished from ordinary cotton by immersing in a strong solution of zinc chloride and distilled water with a few crystals of iodine: both will turn blue but the blue of unmercerised cotton can be washed away while that of the other is permanent. Moreover, with a solution of idoine in cold potassium iodide, mercerised cotton will change colour to blue while ordinary cotton will remain white. This solution is also used for the testing of other vegetable fibres which are steeped in it for about 3 minutes and then washed in a dilute sulphuric acid solution. Jute will then turn orange, flax blue, New Zealand flax yellow and hemp greenish grey. There are also special tests for rayon fibres. Thus, acetone dissolves acetate rayon but not the other three varieties for which special solutions are used. Chemical examination also helps in identifying mixed fibres.

Rough and ready tests are made by burning with matches. Animal fibres would smoulder slowly and give

out the smell of burnt hair and would leave a small bead at the end of the thread. Vegetable fibres would, on the other hand, burn rapidly sometimes with a flame and will leave a whitish ash in a thready form. The charred end will curl slightly for cotton but not for linen or flax. Asbestos fibre will not burn at all and other metallic fibres will only get heated without charring.

There is also the microscopic examination by which both the horizontal and cross section views are noted and compared. The following figure shows these structures of the most important fibres.



1. Cotton.
2. Sea island Cotton.
3. Flax.
4. Mercerised Cotton.
5. Hemp.
6. Jute.
7. Ramie.
8. Wool.
9. Hair.
10. Silk.
11. Tussah Silk.
12. Viscose Rayon.
13. Nitrate Rayon.
14. Cuprammonium Rayon.
15. Celanese.

Commercial analysis or assay of vegtable fibres is done in laboratories with a view to the determination of moisture content and of ash and carbon after complete combustion, hydrolysis or the loss of weight after boiling in 1% caustic soda solution, determination of white residue (of

cellulose) after similar boiling or after exposure to chlorine gas for one hour, the loss of weight (or mercerisation) after cold digestion with a 20% solution of sodium hydrate for one hour and the weight obtained on nitration with a mixture of equal volumes of sulphuric and nitric acids for one hour. With regard to animal fibres, wool and silk, special attention is paid to the action of acids and alkalis. Thus, silk has special affinity for tannic acid and would absorb as much as 25% of its weight while wool has no such property. Concentrated hydrochloric acid dissolves mulberry silk in 2 minutes but will have no effect on tussah silk or wool in that space of time. For further elucidation of this interesting though technical subject larger works may be consulted.

Brush Fibres

As the primary function of all brushes is either to remove dust or dirt or to apply paint, etc. they must necessarily possess a flexible or yielding surface such as can be obtained by the bunching together of a mass of fibres. The range of fibrous materials available is, as we have already learnt, very great and the particular purpose for which a brush or broom is intended determines the type of material used. Thus, for household brooms and brushes like sweeping brooms, scrubbing brushes, carpet brushes, boot brushes, etc. the materials used would be bristle, hair, whisk, fibres of Kitul, paissawa, coir etc. 'Bristle' is the name given to the hairs of hog, pig and boar: they are mostly obtained from Russia, China and India. Other domestic brushes, like clothes or hat brushes are softer and are made from bristle or hairs of badger and horse, the cheaper kinds being made from vegetable fibres. Metal wires are used in the manufacture of cleaning brushes required for bottle cleaning, chimney sweeping, boiler-scrubbing, suede polishing etc. Shaving brushes are mostly made from badger or bristle. For tooth brushes white bristle is generally used. Brushes required for painting or distempering are made from all kinds of fibres, though, for the delicate brushes used by artists for oil painting, water-colouring, etc. spe-

cial fibres are employed e.g. white French bristles pulled from hogs between 1½ to 4 in. long, red sable cut from the tails of the Kolinsky of Siberia, badger hair greyish with a black band and the hairs of fitch, bear or civet. The very finest artist's 'pencils' are made from camel hair which, however, is a misnomer as the hair does not come from the camel but from a species of squirrel indigenous to Russia: it is the softest of all hairs.

Every bristle or hair has a flag end being the tip that grows outwards and a butt end being the root: it grows narrower towards the flag end and has therefore the appearance of an elongated cone. All artists' brushes are so made or 'cupped' that the flag ends being softer always make the painting surface: even where a flat surface is required, the bristles or hair are not cut, being so 'set' as to have the butt ends in the ferrules. Brushes for water colours are fuller and longer than those for oil painting as they have a lighter liquid to deal with instead of a heavy oil. But animal fibres are generally useless for white-washing or distempering, as the washes and colours used for house decoration are mostly alkaline and the vegetable fibres being specially resistant have to be used. In such cases, the ends of the fibres are generally levelled by shears.

While the artist's brushes are mostly hand-made, machinery is now largely employed for manufacturing most types of brushes. Originally they used to be 'pan-set', that is, a required bunch of fibre being made into knots and dipped into a pan of boiling pitch and inserted into the stock. Where brushes are hand-made, the knots are drawn into the holes of the wooden stock or handle from the back of the brush with wires or thread, a veneer being then glued or screwed over the back. In machine-filling, the knots are punched into the solid backs and secured by a staple at the same operation. The stocks or handles are either of wood which may be any hard wood like oak, satin, rosewood, ebony, walnut, mahogany etc. or of ivory, tortoiseshell, celluloid, erinoid and bone. The bone handles used for tooth brushes are generally provided by the thigh-bones of the ox which are shaped and bored with holes for

filling in the bristles. In France, artists' brushes are mostly set in quills. Brushes, where the fibres are not kept in place by wire or thread or ferruled in leather or metal, have to be set in pitch, glue, cement or rubber. Pitch-set brushes are those used for floor-sweeping or dusting. Glue-setting is cheap and is mostly used where brushes do not come in contact with water or anything that would dissolve the glue. For use in water or liquids, cement setting is generally preferred as rubber has a tendency to expand when wet and so to burst the protecting ferrule of metal. Where the fibres are set in rubber, their butt ends are dipped in a solution of rubber and benzol and are subjected to slow vulcanisation in trays of sulphur. Indian sweeping brooms either with or without handles do not require any setting as the fibres or leaves are bunched and tied together by thread or string. In this respect, they resemble the primitive **besom** which is a bundle of twigs or brushwood tied to a wooden handle by means of cane. Light feathers are similarly employed for delicate dusting.

Paper Fibres

Paper has been described as a fabric composed mainly of minute vegetable fibres deposited on to a sieve-like structure from their suspension in water and commingled and felted together to form a homogeneous sheet or web. The supporting tissues of the higher plants are composed of fibrous materials which on isolation from the softer tissues can be reduced to a pulp which can be used in the manufacture of paper. As all fibres containing over 30% cellulose and yielding ultimate fibres which are over 1 mm. in length can be used in this industry, the range of raw materials is certainly wide. But the most important of them all are cotton and flax; in the case of cotton, rags and waste from the spinning mills as well as fuzz or the short fibre on the husk, and in the case of flax, linen rags, spinning waste and scutching refuse form the principal staples: these are used for writing and drawing papers. In the case of hemp, apart from spinning and scutching waste, old cordage is used: this, together with jute waste and old sack-

ing, manilla rope waste, scutching wastes, ends of roving and yarns etc. are used for wrappings and miscellaneous papers. Cereal straws resolved into cellulose by alkaline boiling and bleaching are converted into brown papers and straw boards. Esparto grass with cylindrical wiry stems 3 to 4 feet tall obtained from Spain and Africa and converted into pulp by heating under pressure in a caustic soda solution, forms excellent raw material for printing paper. Bamboo fibres were originally used in China and are now worked in India for making all varieties of paper except newsprint. The Indian equivalent of esparto is Sabai grass which along with **Ulla** grass of the United Provinces and **Moonj** have been used by some Indian paper mills in addition to bamboo pulp. The fibrous residue of the sugar cane after the extraction of juice known as 'bagasse' or '*megasse*' is employed in the paper-mills of Trinidad and Cuba. There are many other fibrous materials experimented upon and successfully tried in the manufacture of paper like paper mulberry, peat etc. The chief considerations are easy procurability in sufficient and continuous quantity at competitive prices and a relatively large yield of fibre embodying the requisite characters. This is perhaps why the bulk of the printing paper is made from wood-pulp obtained **mechanically** or **chemically** from soft coniferous trees like fir, pine or spruce or certain deciduous trees like poplar and aspen. It has been found that wood pulp fibres are somewhat similar to those of cotton, being flatenned in shape and often possessing a number of twists. In the case of **mechanical pulp**, after the logs are debarked, they are forced by hydraulic pressure against rapidly revolving grindstones over which runs a continuous stream of water: the wood so ground is then carried by the water into a pit below where the coarser pieces are separated through a series of strainers; the pulp is then subjected to pressure to expel water and is passed between rollers to be converted into sheets which are packed for export while still wet. In the case of chemically prepared wood-pulp, the chipped wood is boiled with certain chemical reagents under pressure at a high temperature so that

the bulk of the original impurities are removed. The final product receives its trade name from the nature of the boiling agent used. Thus, **soda wood pulp** is prepared by boiling under the influence of caustic soda; **sulphite pulp** by digesting with the bisulphites of alkaline earth metals like calcium or magnesium and **sulphate pulp** by boiling with sodium sulphate and caustic soda. Mechanical wood-pulp, being brittle and impure, is used in the manufacture of news and common printings. Soda wood pulp resembles esparto and cotton pulps, is soft and bulky and is employed in the manufacture of magazine, book printings, cover papers and writings. Sulphite pulp is harder and more transparent and is suitable for admixture in news and printings or for cap papers and wrappings. Lastly, sulphate pulp is strong and tenacious and is therefore unsurpassed for Kraft brown papers. In the modern manufacture of paper, therefore, fibres are of primary importance. **Papyrus**, the paper of the ancients, was thus not paper proper as individual fibres did not enter into consideration. It was prepared from thin long strips of the pith of the papyrus plant laid side by side and gummed over with an adhesive with another similar layer placed atop at right angles, both being pressed together and dried under the influence of sun and then polished with a bone or a stone. The talipot leaves used of yore as writing material in South India were mere strips of leaves of the talipot palm; and ancient parchment was manufactured from the skins of the goat, pig, calf and sheep. The art of making paper from vegetable substance reduced to fibre is ascribed to the Chinese about the first Century A.D.

Cellulose

In the foregoing pages we have often referred to **Cellulose.** This substance is the chief constituent of vegetable fibres It forms the framework of plant organism—the other constituent being the vegetable cells which are embedded therein and which require to be eliminated as a preliminary operation in the process of paper manufacture. Chemically cellulose is a carbohydrate, being com-

posed of the three elements, carbon, hydrogen and oxygen, with the empirical formula, $C_6H_{10}O_5$ which means six atoms of carbon combined with five molecules of water. In the plant structure Cellulose does not exist as a single definite compound but is always accompanied by other substances in intimate association as incrustants. Cellulose in a more or less pure form is found in cotton fibres; but, among other fibres, there are two incrustants namely pectins with which it forms pectocellulose, and lignone forming ligno-cellulose. The pectins are complicated substances containing less carbon and more oxygen than cellulose. A typical pectocellulose is flax fibre. Lignone is a highly complicated compound and is represented in the lignocelluloses of jute fibre and wood-pulp. Industrially, its removal from cellulose is of immense importance (especially in the paper industry) and is achieved by either of the three processes, sulphite, soda and sulphate, described in the last section.

Standard cellulose is obtained from cotton. Its more or less purity accounts for its use in the manufacture of gun cotton for high exposives. Cellulose is amorphous, that is, it is incapable of crystallisation by any known method. It is also insoluble in simple solvents and is inert to the reaction of most reagents. This inertness enables the removal of foreign matter without much danger of attacking the cellulose, thus facilitating the manufacture of paper. Certain solvents have now been discovered which have widened the industrial utility of cellulose. Thus, the manufacture of vulcanised fibre and of filaments for incandescent lamps is due to its viscosity in hot solution with zinc chloride; or the manufacture of artificial silk can be traced to its reaction with ammoniacal cuprical oxide and other reagents. Cellulose has a peculiar affinity for water. Whereas cotton cellulose will absorb about 7% of moisture from the air, regenerated cellulose like artificial silk will absorb about 10%. Cellulose associated with more or less water (even upto 90%) is known as hydrated cellulose which is the basis of making viscose or cuprammonium rayon, of mercerising cotton, or of parchmentising paper.

In the case of greaseproof paper the pulp is 'beaten' in such a manner that the fibres become incorporated with water and assume a sort of gelatinous coat or film. Cellulose (including the compound celluloses) found in Nature has a variety of uses. It is primarily useful as a foodstuff for animals and therefore for man: it provides the basic material for the manufacture of all textiles including linoleum cordage and mattings: it supplies the staple for paper manufacture; it is used constructionally for timber structures, joinery etc,; its derivatives include explosives, artificial silks, glucose, celluloid and plastic material for moulded articles, cement for safety glasses, lacquers and waterproofing and sizing mixtures; its decomposition products include coal, coke, wood distillation products, power gas, industrial alcohol, organic acids, synthetic manures etc. It has been rightly said that this is the age of cellulose as much as of iron and steel; it is little wonder that cotton and other vegetable fibres form the basis of the largest item of international trade.

EPILOGUE

The object of publishing this monograph is to give useful information about fibres and their uses. This book is not intended to be a technical guide for the spinner, weaver or dyer: he may find herein some material that may be useful; nor is the book meant to be an agricultural text-book. But, as pointed out in the last chapter, this being the age of cellulose and therefore of fibres, it is considered necessary to make the average reader acquainted with the structure, extraction, preparation and utilisation of fibres. A knowledge of fibres, however, cannot be complete without some acquaintance with allied non-cellulose substances, like animal and mineral fibres. In short, an endeavour is made to make the book as complete as possible. Though we have a large share in the total fibre production of the world, there are certain aspects of the industry where India has yet lagged behind. For instance, though we have mills where pulp is converted into paper, we have no facilities for converting that pulp into artificial silk. Some research may be necessary as to the suitability of our timbers for rayon manufacture: even if they are found unsuited, there is still scope for converting imported pulp into rayon yarns. There are certain fibres, besides, like flax, hemp, straw and even silk—in the production and manipulation of which we have a vast field for improvement. For such and similar reasons, a fibre-consciousness in the people of this country is necessary which it is the object of this manual to awaken.

BIBLIOGRAPHY

1. Textile Fibres of Commerce—W. I. Hannam.
2. Textile Fibres, their Physical, Microscopical and Chemical Properties.—J. M. Mathews.
3. Textile Fibres and their Use—P. K. Hess.
4. The Structure of the Wood Fibre—F. H. Bowman.
5. Indian Fibres & Fibrous Substances—Cross Bevan & King.
6. Fibrous Plants of India—Royle.
7. Dictionary of Economic Products of India—Watt.
8. The Jute Industry—T. Woodhouse & Kilgeur.
9. Flax Cultivation & Preparation—F. Bradbury.
10. Silk and Wild Silks—Sir T. W. Wardle.
11. Cotton and other Vegetable Fibres—E. Goulding.
12. Analysis and Testing of Textiles—S. D. Vashisht.
13. Linen—A. S. Moore.
14. Paper—A. H. Maddox.
15. Silk—L. Hooper.
16. Straw Hats—H. Inwards.
17. Wool—J. A. Hunter.
18. Asbestos—A. L. Summer.
19. The Brush-maker—W. Kiddier.
20. The Manufacture of Rayon. (Textile, Design & Colour)—W. Watson.
21. Researches on Cellulose—Cross & Bevan.
22. Bleaching, Dyeing, Printing & Finishing—McMyn & Bardsby.
23. Reports of the Committee of the Indian Jute Mill Association.